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**VALIDATION OF ANNAGNPS AT THE FIELD AND FARM-SCALE USING AN
INTEGRATED AGNPS/GIS SYSTEM**

A Thesis

Submitted to the Graduate Faculty of the
Louisiana State University and
Agricultural and Mechanical College
in partial fulfillment of the
requirements for the degree of
Master of Science

in

The Department of Agronomy

by
Glenn M. Suir
B.S., University of Louisiana at Lafayette, 1999
May 2002

DEDICATION

This thesis is dedicated to my parents, Doris Marie Thibodeaux Suir and the late Glenn Ray Suir, for their selfless devotion to my education. Without their support, attaining this degree would not have been possible.

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I extend my sincere gratitude to Dr. Lewis Gaston, Chair of my Committee, for his support, patience, and flexibility in allowing completion of this work. I would like to thank my committee members Drs. Ronald Delaune, H. Alan DeRamus, Wayne Hudnall, and Mr. Wildon Fontenot for their input and guidance, which greatly improved the quality of my work. I would also like to thank the Department of Agronomy for providing me with the opportunity for graduate school training.

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ABSTRACT

Non-Point Source (NPS) pollution models are effective watershed-scale predictors of NPS loadings and useful evaluators of agricultural Best Management Practices (BMPs) and water quality Total Maximum Daily Loads (TMDLs). The work reported in this thesis examined two applications of the AGricultural Non-Point-Source (AGNPS) pollution model: 1) predicting surface runoff, nutrient loading, and sediment yield predictions for an artificially delineated farm-scale watershed; and 2) evaluating relative benefits of different BMPs on reducing sediment accumulation in a lake surrounded by agricultural land. A procedure using identification, extraction, and processing of critical area data using an ArcView Geographic Information System (GIS) was used in both applications. In the first, 30 years of synthetic climate data were used to generate event and source accounting predictions for a multi-use 600-acre research farm in South Louisiana. Runoff water quality predictions for hydrologic cells in standard and artificially delineated watershed simulations were compared. Estimates for sediment, N and P loading in paired watershed cells agreed well, indicating that an integrated AGNPS/GIS system can reliably simulate runoff and NPS loadings for artificially delineated watersheds. Thus, successful implementation of AGNPS for an extracted small-scale region eliminated processing extraneous data, hence reducing simulation time and work required. This approach could allow land operators to initiate and/or evaluate nutrient and site management plans. The second application used AGNPS to evaluate benefits of different BMPs on reducing sedimentation in a small lake. Extensive land clearing in the 1970s for row crop production in Avoyelles Parish accelerated sediment deposition in local waterbodies. Data for depth of the original bottom of an

approximately 2 ha lake below recent (< 30 years) sediment estimated from ^{137}Cs , Pb, clay and organic matter profiles), and sediment bulk density and texture were used to calibrate the AGNPS water quality model for representative hydrologic cells discharging into this lake. Upland erosion and sediment discharge rates predicted under alternative, conservation management practices indicate that sediment accumulation in this lake could have been substantially reduced.

CHAPTER 1

LITERATURE REVIEW

1.1 INTRODUCTION

Degraded water quality is a serious problem in the United States. The Summary of the National Water Quality Inventory: 1998 Report to Congress reported that approximately 35% of the rivers and streams, 45% of the lakes, reservoirs, and ponds and 44% of all estuaries are impaired (USEPA, 1998). Research has shown that impairments can be directly attributed to NonPoint-Source (NPS) pollution. The United States Environmental Protection Agency (USEPA, 1993) defines NPS as that caused by diffuse sources not regulated as point sources and normally associated with runoff or percolation. This type of pollution is often caused by poor management practices and includes soil erosion, nutrients and pesticides in agricultural runoff, pathogens from feedlots, urban runoff and sewage discharge (Tim et al., 1994). The major NPS pollutants of interest for control and regulation include degradable organics, toxic compounds and, most importantly, sediment, organic nitrogen (N) and phosphorus (P) and inorganic N and P (U.S. EPA, 1983).

1.1.1 Agricultural NPS

Routine agricultural practices - the major source of NPS pollution - were found to be responsible for 60% of all surface water contamination (USEPA, 1990). More specific (Figure 1.1), agriculture has been shown to contribute approximately 80-90% of all nitrogen, 70-90% of all phosphorus (Alm, 1990; Gilliland and Baxter-Porter, 1987), and approximately 60% of all total suspended sediment that enters a waterway (Duda et

al., 1985). In addition to the negative downstream affects of NPS pollution, it constitutes a significant loss of valuable essential nutrients and fertile topsoil.

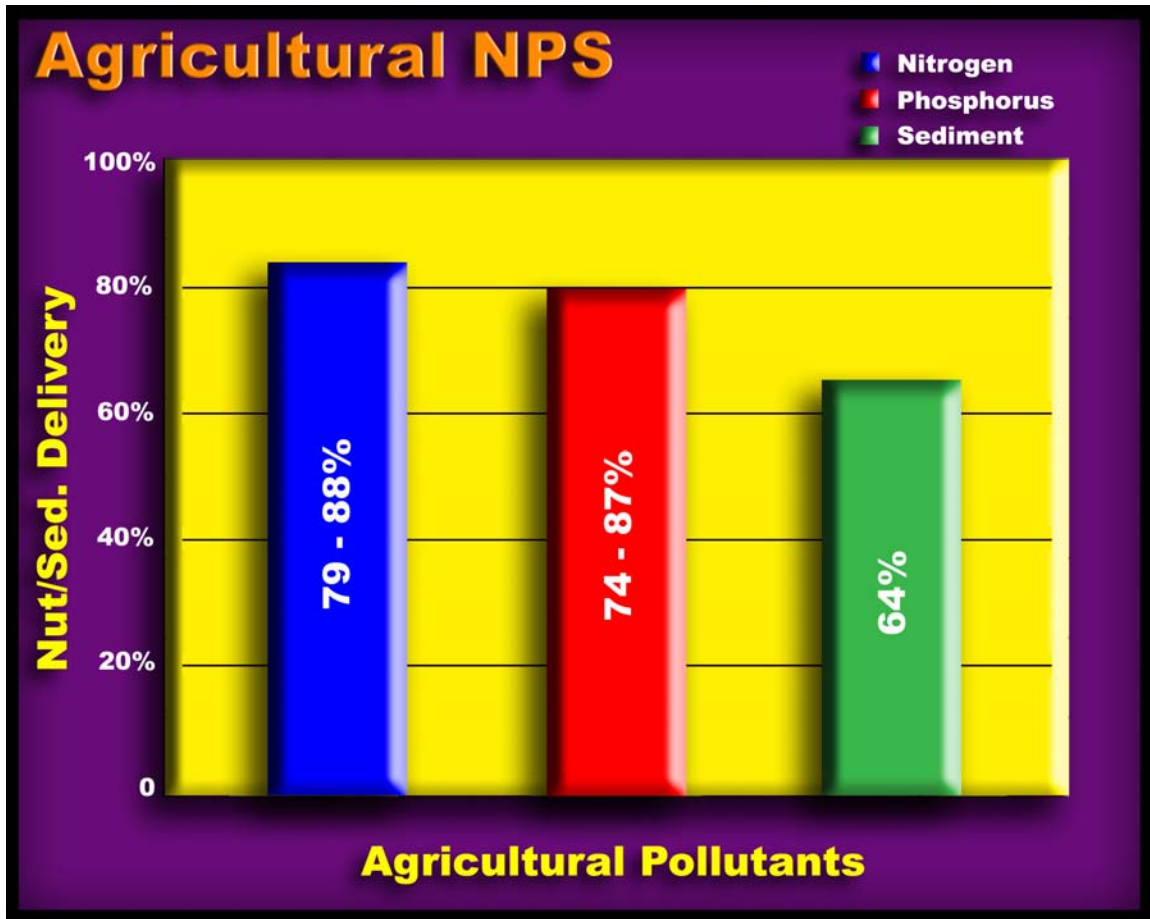


Figure 1.1. Agricultural contributions of total nitrogen, phosphorus and sediment that enters a waterway.

1.1.2 Eutrophication

Siltation and cultural eutrophication are major negative effects of NPS pollution. Mostaghimi et al. (1997) define eutrophication as abundant loading of N and P that leads to an explosive growth of algae, increase in turbidity and temperature, reduction in oxygen levels, decrease in aesthetic value (including bad taste and odor). Eutrophication can occur as a result of natural, or cultural/anthropogenic influences. Cultural

eutrophication occurs rapidly in response to increases in nutrient supply and alters the physical, chemical and biological conditions of a waterbody. Excluding the cost of remediation, it has been estimated that NPS pollution results in \$9 billion in damages annually (Ribaud, 1992).

1.1.3 NPS Pollution Regulation

In an attempt to eliminate pollutant discharge into the navigable waters of the United States, Congress passed the Federal Water Pollution Control Act (FWPCA; better known as the Clean Water Act) in 1972. Its purpose is to restore and maintain the chemical, physical and biological integrity of our waters (USEPA, 1993). Specific objectives of the FWPCA were to eliminate the discharge of pollutants into navigable waters, provide methods for the protection and propagation of fish, shellfish, and wildlife and establish waste treatment management planning processes. However, Section 402 of the FWPCA, a pollution discharge regulatory permit system, excludes agricultural stormwater discharges and return flows from irrigated agriculture (USEPA, 1993). This initial exclusion of NPS pollutants from the FWPCA regulatory system prompted citizen lawsuits and have forced the USEPA to establish a technology-based national water pollution standards and regulatory system. The FWPCA requires each state to periodically identify and list (FWPCA sections 303 and 305) all impaired waterbodies within natural watersheds that fail to meet water quality standards (Wastewater Digest, 2000). In addition to this list of impaired waterbodies, each state is required to establish Total Maximum Daily Loads (TMDLs), the maximum amount of pollutants that a waterbody can assimilate and still meet water quality standards.

1.1.4 NPS Pollution Management

In addition to establishing and complying with TMDLs, states have the monumental task of evaluating and recommending viable solutions for NPS reductions. The current approach to reducing NPS pollution is implementation of watershed-scale agricultural Best Management Practices (BMPs). Simply, BMPs are a set of field activities that provide the most effective means of reducing NPSs (Black, 1996). However, because of the diffuse nature of NPS and the high expense of monitoring and research, solutions to NPS pollution have been difficult to formulate and evaluate. Also, the often complex data necessary for reliable management decisions have not always been readily available. Consequently, hydrologic models and decision support systems have gained wide acceptance as cost-effective tools for predicting NPS loadings, developing and evaluating the effects of BMPs and establishing TMDLs (Tim et al., 1994).

1.1.5 Models

Models are simplified mathematical representations of real systems, processes, or objects. They are often created to test hypotheses, aid data acquisition, allow for simulation or prediction, improve a quantitative understanding of a system and enhance communications. Hydrologic models aid decision making and planning in several different ways. Models provide forecasts of current and alternative impacts on water quality, detail NPS processes, establish critical areas, rank alternative measures and are often the only means of predicting water quality impacts for non-monitored sites (Novotny and Olem, 1993).

1.1.6 Watershed data

A major difficulty with NPS water quality modeling is the spatially variable characteristics of watershed systems. Therefore, practicable but accurate, water quality modeling requires that the spatial elements within a watershed system, such as elevation, slope, soil characteristics, land-use, and climatic conditions, be a generalized representation of the real-world features. Data availability, scale and procedural limitations inherent to watershed modeling clearly necessitate this simplification. Until recently, hydrologic models have been unable to adequately manage and represent this required spatial component. Now, proper management of NPS pollution and watershed data is becoming increasingly feasible via the use of a Geographic Information System (GIS) and increasingly available spatial data.

1.1.7 Geographic Information System

A GIS is an organized collection of computer hardware, software, geographic data, and personnel designed to efficiently capture, store, update, manipulate, analyze and display all forms of geographically referenced information (Booth, 1999). According to Goodchild (1993), a GIS can be utilized for three essential tasks: pre-processing, analysis, and post-processing. The preprocessing task is the projecting, classifying and reformatting of data into a form that can be analyzed. The task of analyzing is the ability to examine, model and further manipulate complex processes. Finally, post-processing is the ability to create reports and visually represent processed and analyzed information.

1.1.8 The GIS and Model Integration

The integration of a GIS and water quality model allows for establishing relationships between watershed parameters and their spatial attributes. Some

GIS/Model systems are fully integrated, with all functions processed within the GIS platform. Unfortunately, the majority of available GIS/Model systems contain only a linked integration. This involves stand-alone components (GIS and Model) that create, support and share relevant information. It should be noted that most GIS platforms allow for supplemental integration through the construction of function-specific extensions and script plug-ins.

1.2 NPS MODELS

In recent years the number of available water quality models have increased. The capabilities and scope of these models range from the simple empirical (minimum data required, hydrology independent, export coefficient based) model to the complex mechanistic (large data required, hydrology dependent) model. When selecting a model and modeling method, the user should utilize the simplest model that will satisfy the project objectives, use a quality prediction model consistent with available data and only predict with suitable parameters and time scale (Novotny, 1995).

1.2.1 Model Uncertainty

A cause of concern in modern modeling is the lack of uncertainty analyses. Uncertainty, a condition of incomplete or unreliable knowledge, exists in scientific projections of future conditions because of induction and is an essential component of planning and decision-making (Chapra and Reckhow, 1983). Hydrologic model uncertainty, in particular, is related to the relationship among the variables characterizing the dynamic behavior of systems, including uncertainty about the value of the parameters representing system behavior, uncertainty associated with predictions of the future behavior of the system, the design of uncertainty reducing programs (Beck, 1987) and

size of watershed (Figure 1.2; Novotny and Olem, 1993). Uncertainty can be estimated and reduced by use of standard statistical software and through model calibration and validation. Model calibration is the process of varying uncertain model input over likely ranges of values until a satisfactory match between simulated and measured data is obtained. Validation is the process of demonstrating that the calibrated model is an adequate representation of the physical system (Bhuyan et al., 2000). In addition to model uncertainty, the processing and simplification of data with a GIS can potentially contribute to uncertainty. One method of reducing GIS related uncertainty is to use the most applicable and comprehensive data sets available.

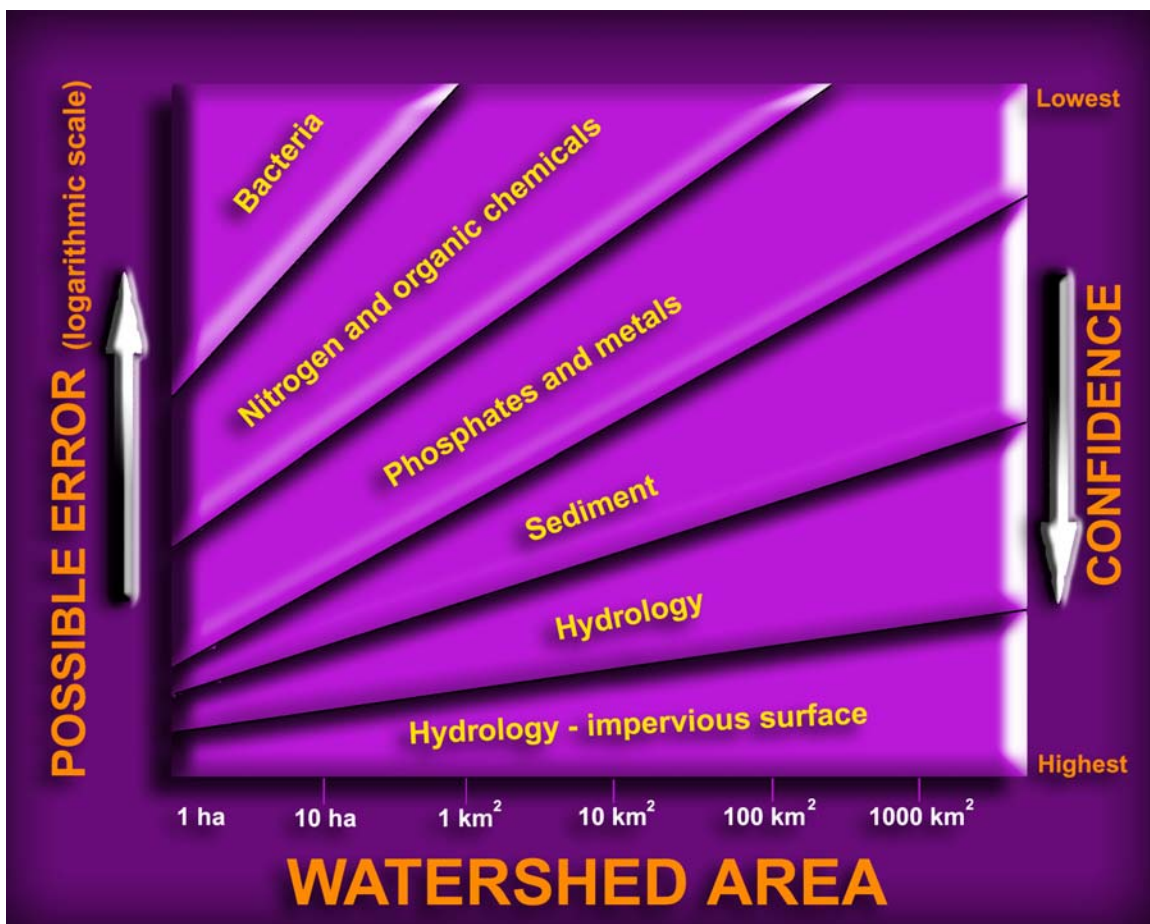


Figure 1.2. Relative accuracy and reliability of hydrologic models of diffuse pollution. Accuracy and reliability decreases with the increased complexity and size of the modeled system.

1.2.2 ANSWERS

ANSWERS (Areal Nonpoint Source Watershed Environment Response Simulation; Beasley et al., 1981) was developed at Purdue University. It is an event-based single-storm distributed parameter model. The model divides a watershed into uniform cells and simulates the process of interception, infiltration, surface storage, surface flow, subsurface drainage, sediment detachment, and movement across the cell. Considerable amounts of spatial data are required for watershed simulations and predictions. Nutrients are simulated using correlation relationships between chemical concentrations, sediment yield and runoff volume (Novotny and Olem, 1993).

1.2.3 BASINS

BASINS (Better Assessment Science Integrating Point and Nonpoint Sources; Lahlou et al., 1998) is an EPA software package that integrates GIS, nationally supported watershed data and watershed and stream models. BASINS uses an AVENUE-scripted object-oriented interface, the SWAT, WinHSPF, and QUAL2E models and a compilation of generalized and site-specific data to perform three primary functions. The functions are to facilitate examination of environmental information, to provide an integrated watershed and modeling framework and to support analysis of point and non-point source management alternatives.

1.2.4 CREAMS

CREAMS (Chemicals, Runoff, and Erosion from Agricultural Management; Knisel, 1980), is a USDA-ARS lumped parameter, deterministic, continuous simulation model. It is based on the steady-state mass balance of sediment transport, detachment and re-deposition of surface runoff, but does not address base-flow (Novotny, 1995).

This field-scale model uses USDA SCS (Soil Conservation Service) curve numbers (USDA,1972) for hydrology and modified USLE (Universal Soil Loss Equation) to simulate sediment, N, P and pesticide load from agricultural sources (Novotny and Olem, 1983).

1.2.5 HSPF

HSPF (Hydrologic Simulation Program - FORTRAN; Bicknell et al., 1993) is a one-dimensional stream network, lumped parameter, continuous simulation model. The model simulates snow accumulation and snowmelt, water runoff, interflow, groundwater and evaporation, sediment yield, nutrient transformation and transport, pesticide transformation and transport. It includes routines for channel flow, and stream and reservoir water quality. HSPF does a good job of including entire hydrologic cycle, detailing water quality mechanisms, and is a versatile and flexible system. However, the model is not user friendly, requires considerable amount of time for calibration, is sensitive to time step, and has a poor validation track record (Novotny and Olem, 1983).

1.2.6 SWRRB-WQ

SWRRB-WQ (Simulator for Water Resources in Rural Basins - Water Quality; Arnold et al., 1995) is a USDA modification of the CREAMS model that functions in a continuous simulation daily time-step mode for basin-scale predictions. SWRRB-WQ simulates meteorology, hydrology, crop growth, sedimentation, flood plain degradation and aggradation, N, P and pesticide movement. The model includes channel processes and subsurface flow, derives runoff from NRCS curve numbers and erosion from RUSLE (Revised Universal Soil Loss Equation). Its CREAMS components are used to derive nutrient and pesticide predictions (Novotny and Olem, 1993).

1.2.7 SWMM

SWMM (Storm Water Management Model; Huber and Dickinson, 1988) is an EPA continuous and single event storm-water and combined sewer overflows quantity-quality simulation model. The quality simulation component uses the build up and wash-off, rating curve, constant concentration and USLE methods for predicting pollution. The quantity simulation component uses nonlinear reservoir, kinematic wave, and complete dynamic equations (Novotny and Olem, 1993).

1.3 AGNPS

AnnAGNPS (Annualized Agricultural NonPoint Source Pollution Model; Cronshey and Theurer, 1998) is a deterministic, distributed parameter, single event simulation model that has become the water quality model of choice for many researchers. The latest version of the model (AnnAGNPS 2001) incorporates NRCS curve numbers and hydrograph routing procedures for hydrology, the revised universal soil loss equation (RUSLE; Renard et al., 1997) for sediment, and remotely sensed or observed site-specific data to predict runoff, sediment, attached and dissolved N and P, and organic carbon. As outlined by the Agricultural Research Service (ARS) and NRCS (2001), the model consists of three vital processing and related program components. These include input and climate data generation and editing programs, stream network and stream corridor processes and models, and output reformatting and analysis programs.

1.3.1 AnnAGNPS Input Generation and Editing Programs

The input generation process consists of data acquisition, data reformatting and data conversion. The programs used for input generation include software utilities, an

integrated GIS assisted computer program, and the TopAGNPS (Topographic AGNPS), AGFlow, and Input Editor executable files. The GIS, TopAGNPS, and AGFlow programs are used to generate topographically related data required to compute hydrologic, hydraulic, and watershed parameters. These parameters are initialized, revised and finalized via the Input Editor programs specific GUI (Graphical User Interface) window for each of the models 33 input categories. Table 1.1 illustrates both the sections that contain each data category and the suggested order of use. Each data category contains a set of input parameters that are required for proper AnnAGNPS execution. An example of these parameters is the set of data contained within the soils data category. The soils input parameters include (among others) soil series, horizon depths, hydrologic soil group, K-factor, albedo, impervious depth, bulk density, sediment ratios, organic N ratio and base saturation. In addition to input data, watershed climate data must be obtained or generated. The climate data required (Table 1.2) may be obtained via historical record, or generated using the Generation of weather Elements for Multiple applications (GEM; Johnson et al., 2000) program. The GEM generator utilizes established regional weather conditions to generate user specified and AnnAGNPS required climate data.

1.3.2 Stream Network and Stream Corridor Processes and Models

Center for Computational Hydroscience and Engineering 1 Dimensional model (CCHE1D, Vieira and Wu, 2000) and Conservational Channel Evolution and Pollutant Transport System (CONCEPTS; Langendoen, 2000) are the stream network processes models. CCHE1D is a stream corridor model that estimates long-term sediment loads and morphologic changes in channel networks, evaluates the effectiveness of erosion

control and channel remediation measures on sediment yield, and analyzes the influence of land use changes and agricultural management practices on sedimentation (Vieira and Wu, 2000). The CONCEPTS model simulates one-dimensional flow, graded-sediment transport, and bank-erosion processes to predict the dynamic response of flow and sediment transport to in-stream hydraulic structures (Langendoen, 2000).

1.3.3 Output Reformatting and Analysis

The output processes are controlled by the AnnAGNPS and Output executables. The AnnAGNPS program is used to calculate soluble and particle-bound nutrients (N, P and organic C), water and sediment yield by particle size class and source, field pond water and sediment loading, feedlot and point source contributions to nutrient concentrations, as well as individual feedlot potential ratings. The Output Processor program converts the raw data generated by the model into a tabular formatted file that includes table headings and data summaries.

1.4 CASE STUDIES

For more than a decade, AGNPS has been used worldwide for water quality and NPS pollution predictions. The following articles were selected as case studies since they show the progress that the model has made, and address the issues imperative to successful integrated AGNPS/GIS predictions. These projects included a terrain analysis (Panuska et al., 1991), sensitivity analysis to grid-cell size (Vieux and Needham, 1993), validation study using an integrated AGNPS/GIS system (Mitchell et al., 1993), assessment of BMPs on small agricultural watersheds (Mostaghimi et al., 1997), sediment yield predictions (Perrone and Madramootoo, 1999), and calibration using remotely sensed data (Bhuyan, 2000).

1.4.1 Terrain Analysis: Integration into the AGNPS Model

Panuska et al. (1991) studied various techniques for utilizing terrain data to estimate essential watershed hydrologic attributes. This 1991 study used Digital Elevation Model (DEM) data, a contour-based AGNPS-C model, and a grid-based AGNPS-G model to assess the model's ability to accurately represent the stream network for the Water Quality Research Unit Watershed No. 2 in Treynor, Iowa. Results showed that both of the terrain-based models, AGNPS-C and AGNPS-G, produced hydrologic models similar to that of AGNPS v.2.52. A sensitivity analysis showed that cell size and resolution of the DEM appeared to heavily influence the AGNPS-C and AGNPS-G ability to characterize terrain variability. The researchers found that both contour and grid versions of the AGNPS model performed well, but additional work was required to improve the model algorithms.

1.4.2 Validation of AGNPS for Small Watersheds Using an Integrated System

Mitchell et al. (1993) evaluated the suitability of a GIS/AGNPS integrated model system for predicting runoff and sediment yield from small, mildly sloping central Illinois watersheds. Half of the fifty sediment yielding runoff events were used to calibrate the model, and averaged calibrated input was used for the remaining events to validate the model. The resulting simulated total annual runoff varied from 65 to 151%, and total annual sediment yield varied from 29 to 557% of the observed data. The model algorithms were unable to accurately describe the watersheds small slope and area. Despite their discrepancies, Mitchell et al. (1993) concluded the model is a valuable tool for water quality management, but required further work to improve accuracy and applicability.

1.4.3 NPS Pollution Model Sensitivity to Grid-Cell Size

Baxter and Needham (1993) studied the effects of computational element size (cell size) selection on accuracy of NPS pollutant predictions. A sensitivity analysis was performed on input parameters derived from varying cell sizes within a 282-ha watershed located near Morris, Minnesota. Results indicate that cell size strongly influenced sediment prediction components of the AGNPS model. Sensitivity analysis showed sediment yield to be the most dependent on the flow-path length, therefore, on cell size. The delivery ratio showed an increase of 71% when cell size alone was adjusted. Clearly, cell size is not an arbitrary choice. It should (with assistance of a GIS) be based upon the scale appropriate for capturing the spatial variability.

1.4.4 Assessment of Management Alternatives on a Small Agricultural Watershed

Mostaghimi et al. (1997) used AGNPS to assess BMP effects on water quality and quantity in the Owl Run watershed in Fauquier County, Virginia. The model was calibrated using two previous years of data collected from within the 1,153-ha watershed, and was validated using runoff event data for three separate years. Results showed that AGNPS predictions compared favorably to the observed data. Relative errors for sediment yield, N and P loadings, were only 24, 14, and 9% respectively. Seven BMP scenarios (current and six alternatives) with long-term goals of 40% reduction in loadings were applied to strictly defined critical areas. Five of the seven BMP scenarios for this study did not meet the long-term goal. Results indicated that with more loosely defined critical areas, the AGNPS model is a suitable model for NPS predictions and a useful management tool. These researchers found input data preparation very time consuming and difficulties with data contributed to inaccuracies of predicted values.

1.4.5 Sediment Yield Prediction Using AGNPS

Perrone and Madromootoo (1999) evaluated the ability of the AGNPS model to predict sediment yield for a small Quebec watershed. The model was calibrated using adjusted NRCS curve numbers and USLE factors for twelve runoff events. The model averaged an error of 28% and a coefficient of performance of 0.01 for all sediment yield predictions. Six of the twelve events were over-predicted, six events were under-predicted, but eight among these predicted to within $\pm 15\%$ of the observed yield. The results indicated that though AGNPS was fairly reliable for surface runoff, careful attention should be given to the selection of seasonally adjusted USLE C factors and particle size distribution.

1.4.6 Water Quality Assessment for Cheney Reservoir Watershed

Bhuyan et al. (2000) used model calibration and remotely sensed data to reduce landuse, temporal variation, watershed conditions and prediction uncertainty for a Kansas watershed simulation study. The AnnAGNPS model, run in the single event mode, gave adequate results for the smallest three of five sub-watersheds modeled but could not account for the decreased uniformity of climate conditions typical of the larger sub-watershed. Bhuyan et al. (2000) concluded that the AGNPS model is a valuable decision support system tool for resource managers, but recommended that sub-watersheds be divided into adequately sized catchments and that calibrations be performed for all sub-watersheds that contain different landcover practices and soil texture.

1.5 SUMMARY

Models are becoming essential tools for reducing or managing NPS pollution. As modeling becomes more commonly used, it must be remembered that models contain

uncertainties and limitations and should not be used as a NPS end point. Among various water quality models, however, AnnAGNPS (aside from minor shortcomings) has proven accurate in simulating watershed systems and NPS pollution. Successful implementation of an integrated AnnAGNPS/GIS could be used as a decision support system for water quality planning and management.

Table 1.1. AnnAGNPS input data sections, data categories and suggested order of operations.

DATA SECTIONS	DATA CATEGORIES
File Identifier	AnnAGNPS Identifier Watershed Data
Simulation Period Data	Simulation Period Data
Cell Related Data	Cell Data Cell Profile Data
Field Related Data	Field Data Field Management Data Operations Data Operations Reference Data Contour Data Irrigation Application Data Fertilizer Application Data Pesticide Application Data Strip Crop Data
Reach Related Data	Reach Data Reach Geometry Coefficients Reach Nutrient Half-life Impoundment Data
Other Component Data	Feedlot Data Feedlot Management Data Gully Data Point Source Data
Reference Data	Crop Data Fertilizer Reference Data Landuse Reference Data Pesticide Reference Data Runoff Curve Number Data Soil Data
Output Related Data	Global Output Specification Reach Output Specification Source Accounting Output Specification Verification Data
End of Data	End Data

Table 1.2. AnnAGNPS climate data section and categories

DATA SECTION	DATA CATEGORIES
Climate Data	Precipitation Maximum air temperature Minimum air temperature Relative humidity Sky cover Wind speed

CHAPTER 2

FARM AND FIELD-SCALE MODELING

2.1 INTRODUCTION

Water quality models are becoming an increasingly accepted tool for NPS predictions, BMP evaluations and overall aid in addressing water quality concerns. These models provide quantitative information, test hypotheses, allow for predictions, enhance communications, and provide an organized view of hydrologic systems. Water quality models are being used by government agencies, research institutes and private consulting firms to simulate real world conditions and processes in order to quantify TMDLs and determine sources of water pollutant loadings. The trend in water quality modeling is away from the lumped parameter models and towards distributed parameter models. Distributed parameter models are robust and capable of accurate predictions, but are constrained by high data input and processing requirements. Additional limitations are a lack of available data and instructional documentation.

Many water quality models are at least partially integrated with a GIS, and are able to assist in the reduction of data processing, input, and analysis. The use of GIS to manage spatial data has partially resolved the input problems associated with distributed parameter models. However, since most integrated systems are still less than ideal and essential digital data are often unavailable, the amount of data processing required remains a major hindrance.

2.1.1 Farm and Field-Scale Modeling

Water quality modeling is almost exclusively being performed at the watershed scale, however, there are practical reasons for small or, management-scale simulations.

Of the conventional field-scale simulations being performed, most are done using a model's single-cell feature. This feature greatly simplifies the delineation and data acquisition/entry processes, yet strongly ignores vital variability and potentially sacrifices accuracy. At the management-scale more comprehensive input data can be compiled, accurately accounting for spatial variability and resulting in more accurate predictions. Farm-scale modeling could be used as nutrient management tools allowing land operators and district conservationists to predict long-term effects of various management practice scenarios. The field-scale modeling procedures discussed in this study could be used to calibrate the model for BMPs.

The primary objective of this research project was to compare the procedures and simulation results, of a conventionally delineated, large-scale watershed versus an artificially processed farm-scale delineation. Applying the model to a small-scale Area Of Interest (AOI) should reduce extraneous data and reduce data processing and simulation time. A secondary objective of this project was to explore the methodology required for applying a water quality model to a field-scale research plot. This type of simulation can be used with edge of field samplers for easy calibration and validation. The final objective of this project was to create an instructional guide (chapter written as tutorial) for using a water quality model and GIS integrated system for small-scale nutrient and resource management.

2.1.2 Area Of Interest

The Renewable Resources Department of the University of Louisiana at Lafayette (ULL) recently initiated a “Model Farm” project. Objectives are to demonstrate improved water quality by adoption of sustainable agricultural practices that improve

water quality, and to validate implemented BMPs. The ULL Experimental Farm (Cade Farm) has been designated as a “Model Conservation Farm” by the Natural Resources Conservation Service (NRCS) and is the AOI for this project. This 600 acre multi-use research farm is located in St. Martin Parish near Cade, Louisiana (Figure 2.1). The farm contains five soil types, an elevation change of over thirty feet, roadways, a borrow pit, and twenty permanent structures. Its diverse land uses and land features include, aquaculture, dairy, beef, wetlands, woodlands, sugarcane, native grass pasture, water treatment, orchard, row crop, and swine operations (ULL-Renewable Resources, 1999). Given diverse soils, topography, land-use/land-cover, and unique drainage conditions, the Cade Farm is ideal for this farm and field-scale delineation and simulation study.

2.1.3 AnnAGNPS and GIS Integration

The Annualized Agricultural NonPoint Source Pollution Model (AnnAGNPS; Cronshey and Theurer, 1998) v2.0, was the water quality model chosen for this research project. The AnnAGNPS model was selected based on its robust nature, reputation, and because it is endorsed and supported by the Louisiana Department of Environmental Quality (LaDEQ). All AnnAGNPS modules, datasets, and reference documentation were obtained via download from the National Sedimentation Laboratory internet site <http://www.sedlab.olemiss.edu/agnps.html>. The downloaded components of AnnAGNPS were saved in the C:\AGNPS directory. This directory was created and arranged to resemble the structure tree in Figure 2.2. This directory structure is important since the batch and script files used during the course of this project are directory dependent and specific. To reduce the amount of batch and script file editing, the BASE directory system was established for this project. This system forces all AnnAGNPS

executables and batch files to operate exclusively within the BASE project, which is located within the C:\AGNPS\Agnps2001_watershed_studies\Base directory. Switching from one project to another only requires the renaming of a project folders to the BASE folder. For example, renaming the C:\AGNPS\Agnps2001_watershed_studies\Cadefarm folder to C:\AGNPS\Agnps2001_watershed_studies\Base. It is recommended that all project folders contain a sub-folder with the projects original name. This makes future identification of projects much easier and provides a dedicated folder for the storage of unique project information.

The Environmental Systems Research Institute (ESRI) ArcView v3.2 program, and Spatial Analyst v2.0 extension, was the GIS package chosen for this project. ArcView, the world's most popular desktop GIS and mapping software, is a dependable system that at present is partially integrated with the AnnAGNPS model. It is important to note that all default extensions should be loaded, and working directory and projections set when any ArcView project is created.

2.1.4 Project Utilities

A number of program utilities were used to assist with file and format conversions, data editing and project dataset management. In addition to these utilities, extensions and scripts were obtained or created to assist with data management within the AnnAGNPS/ArcView system. The MS-DOS prompt edit feature was also used to create and edit the batch files that are used to copy, delete and move project files, as well as initiate the AnnAGNPS executable files. These batch files contain the paths of specific drive locations and should be assessed and edited on a per task basis. To assist with successful batch file executions, all data should be placed in the appropriate project

folder. For example, all shapefile data should be placed or saved in the project 4_ArcView_Datasets\shapefiles folder.

2.2 DELINEATION

Delineation refers to the defining or outlining of a catchment or watershed. Where watershed is defined as “the natural or disturbed unit of land on which all of the water that falls, collects by gravity, and fails to evaporate, runs off via a common outlet” (Black, 1996). Delineation allows for the reduction of one large watershed into smaller more distinct parcels of land. These parcels, or cells, allow for better accountability of spatial and hydraulic variability within the watershed.

Water quality modeling is conducted using large-scale conventional delineations. Minimal research has been performed to explore the applicability and precision of AnnAGNPS at the management-scale. Accurate predictions at this scale would reduce data gathering and processing, allowing for use of more detailed site-specific data.

2.2.1 Conventional Delineation

Delineation datasets are used by the AnnAGNPS/GIS integrated system to define independent hydrologic units within a specified watershed, and are used to determine flow paths, slope, aspect, stream network and hydrologic cells. The major delineation datasets required are, digital elevation models (DEMs), stream/reach (RF3 or NHD) data, topographic (Topo) map data, hydrologic unit code (HUC), and political and hydrologic boundary data (Figure 2.3). These datasets are most useful in digital format and, for the state of Louisiana, most can be obtained from the Louisiana State University (LSU) Atlas GIS internet site <http://atlas.lsu.edu> or from the Louisiana GIS CD, obtainable free of charge at http://www.osradp.lsu.edu/gis_cd.htm. RF3 data can be obtained from the

Environmental Protection Agency (EPA) website

<http://www.epa.gov/OST/BASINS/STATES/LA/>.

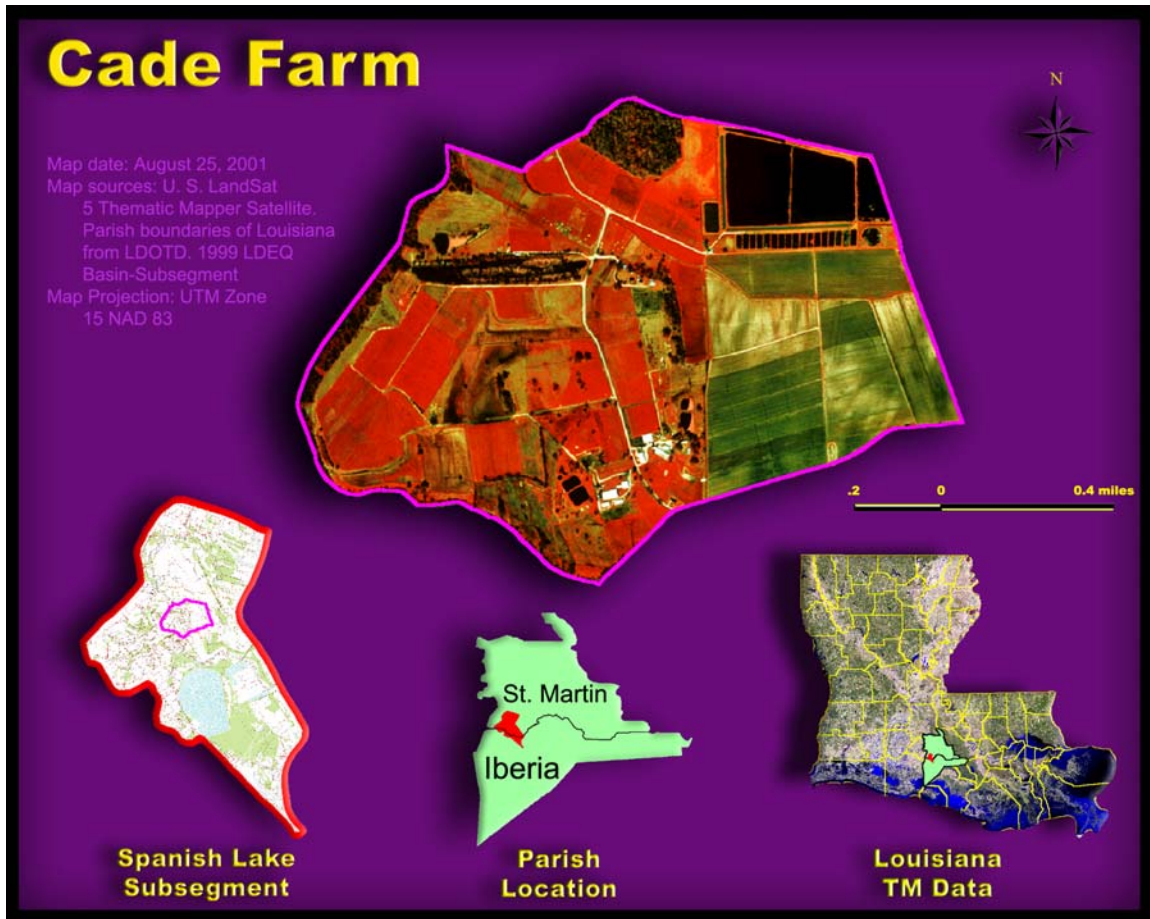


Figure 2.1. The Cade farm-scale Area Of Interest location within state, parish and sub-segment boundaries

2.2.2 Data Preparation

To ensure accurate watershed delineation, datasets must first be identified, gathered, and processed. State of Louisiana places data, USGS parish data, LaDEQ sub-segment data, and USGS 1:24,000 (24k) scale quad themes within the Louisiana GIS CD were added to a new UTM zone 15, NAD 1927 projected ArcView project. These datasets were overlaid and used to identify the Cade farm AOI and corresponding names

of additionally required datasets. ArcView's "Identify" function was used to identify the names of quadrangles, parishes, and watersheds and sub-segments that contain any portion of the Cade AOI. The AOI was determined to lie within the Spanish Lake sub-segment (HUC# 08080103), which is a sub-basin of the Vermilion-Teche watershed. This sub-segment lies within the Broussard, New Iberia North, Parks and Youngsville quadrangles. The Atlas site was used to download 7.5 degree (30 meter) DEMs, and Topo maps for the four quadrangles. The Topo maps were downloaded as GeoTIFF files, added as an image data source to the Cade project and edgematched using the Image-Tools extension v2.5. The resulting Topo map was then used to reconfirm the AOI and saved as the base layer to which all spatial data would be confirmed and/or aligned.

With the Spatial Analyst extension loaded, the four DEM files were added by selecting the "Import Data Source" option under the "File" menu, selecting the USGS DEM file type, and then loading each DEM individually. The newly created grid files were saved as their original quad name in the project 4_ArcView_Datasets\grids folder. With the Grid Analyst Extension v1.1 loaded, the "Mosaic" option was selected from under the "Transform Grid" menu, and all four DEMs were merged into one continuous grid file.

The EPA's Basin site was used to download relevant RF3 reach data for the Spanish Lake sub-segment. This file was unzipped using the Winzip program, and the resulting shape-files were saved to the projects shapefile folder. This RF3 theme was added to the working ArcView project and its precision was verified using the Topo image. Due to a lack of accuracy, the RF3 file was edited to more closely resemble the base topo map. This was accomplished by making the RF3 file active, selecting the

“Start Editing” function under the "Theme" menu, and then selecting the “Vertex Edit” tool. This tool allows the user to move any vertex contained within a line or polygon. All relevant lines were adjusted until accurately aligned. All edits were then saved, and the “Stop Editing” function was selected from the Theme menu.

Accurate representation of reaches is extremely important to the delineation process. Significant error can be introduced during delineation of landscapes with little topography and minimal slope, both typical to South Louisiana landscapes. In addition, since reach width is often less than the raster cell resolution of a 30 meter DEM, accuracy is often lost. To overcome these problems, it is becoming commonplace in water quality modeling to use the “burn-in” method. This process converts the RF3 shapefile to a grid format, assigning a user-specified value from the attributes table to each individual raster cell. Since RF3 files contain data falling outside of the AOI (extraneous data) it is sensible to clip unnecessary reaches from the file. A "New Polygon" theme was created from the "View" menu, and saved as RF3_border. The "Draw Rectangle Button" was selected, a rectangle slightly larger than the Spanish Lake sub-segment was created, and all edits were saved. The ArcView geoprocessing extension was loaded, and the "Geoprocessing Wizard" was then selected from under the "View" menu. The “clip one theme based on another” function was selected, the RF3 file was clipped based on the RF3_border overlay theme, and RF3_clip was specified as the output file. Since every raster cell value within the final DEM must have a minimum value of "1", it is imperative that at least one data field within the attribute table satisfies this requirement. With the RF3_clip theme active, the “Open Theme Table” button was selected from the toolbar, and the table was made editable. The “Add Field” function

under the "Edit" menu was selected, and a number field named "DEM" was created. With all records selected, and the new DEM field active, the "Calculate" button was selected, the number "1" was typed into the text box, and edits were saved and stopped. The RF3_clip file was then converted using the "Convert To Grid" function under the "Theme" menu. To ensure proper conversion, the original RF3_clip file was selected as the Output grid extent, the original DEM file was selected as the Output grid cell size, and the DEM field was selected for cell values. The new RF3_grid file was then merged, or "burned into" the DEM file using the Grid Analyst Extension's "Merge" option from under the "Transform Grid" menu. The values for the new RF3 portion of the DEM file are often exaggerated to force more accurate calculations of flow path and stream network during delineation. At this point the conventional DEM preprocessing was complete.

2.2.3 Artificial Delineation

Since the conventional delineation process only locates naturally occurring catchments, the delineation of a farm-scale area must be forced by creating an artificial berm around the AOI. The artificial delineation DEM was not prepared until after the TopAGNPS and AGFlow executions of the conventional delineations have been completed. The final DEM file created using the conventional delineation process was used in the artificial delineation process. ArcView's "Convert to grid" option under the "Theme" menu was used to copy the final DEM file to the C:\AGNPS\Agnps2001_watershed_studies\Cade_farm\4_ArcView_Datasets\grids directory, and saved as farm_dem.grd. With the farm_dem.grd, conventionally delineated cells, and the related topo image themes viewable within ArcView, a new

shapefile was created using the "New Theme" option from the "View" menu. The shapefile, in the polygon feature type, was saved as Cade_berm.shp in the Cade_farm\4_ArcView_Datasets\shapefiles directory. With the Cade_berm theme active, the "Draw Rectangle" button was selected from the toolbar. The AOI was located on the topo image, and the rectangle tool used to draw a rectangle large enough to capture all the reach and source cells directly contributing to the AOI. The rectangle also contained a portion of the natural stream network that was downstream from the AOI. An additional rectangle was drawn at a distance of approximately 90 meters (three raster cells) beyond the first rectangle. With both rectangles selected, the "Combine Features" option was selected from under the Edit menu. With the Cade_berm theme active, the "Open Theme Table" button was selected from the toolbar and the ID value changed using the "Edit" button. The ID value was given a value greater than the largest elevation value within the DEM file. Edits were saved and stopped, and the Cade_berm shapefile converted to grid by selecting the "Convert To Grid" option from under the "Theme" menu. The resulting file was saved as Cade_berm, stored in the Cade_farm\4_ArcView_Datasets\grids directory, received an output grid extent the same as Cade_berm, an output grid cell size the same as the DEM file, and the ID field for cell value. With the Cade_berm grid file active, the Grid Analyst Extension was used to "Merge" the Cade_berm and DEM grid files together. Creating a second new polygon shapefile theme, and drawing a rectangle larger than the previous ones, allowed for the extraneous portions of the newly merged artificial DEM file to be removed. With the artificial DEM file active, the "Extract Grid Theme Using Polygon" option from under the "Grid Analyst" menu was used to extract the artificial portions of the DEM grid using

the new polygon file. The resulting grid file was saved as Cade_DEM, and placed in the Cade_farm\4_ArcView_Datasets\grids directory. Finally, with the Cade_DEM theme active and the Single Cell Editor extension loaded, the raster values for the portion of the berm that crosses the natural outlet were reduced to match the nearby reach values. This was done by selecting the "Single Cell" button from the toolbar, clicking the DEM's raster cell, selecting the raster cell's new value from within the value matrix, specifying the path and filename of the new file, and selecting "create new grid theme". At this point the Artificial farm-scale delineation DEM preprocessing was complete.

2.2.4 Field-Scale Delineation

Field-scale delineations were performed on four two-acre pasture paddocks located within the Cade farm. These plots contain a warm-season base of *Cynodon dactylon* (common bermudagrass) and *Paspalum notatum* (Pensacola bahiagrass), which provide two replications each of Conventional Grazing (CG) and Managed Intensive Grazing (MIG) operations. All plots are contained within a 0.61 meter high earthen berm, and are fixed with a 0.5 meter H-flume, and an automatic ISCO refrigerated sampler. X, Y, and Z, and USGS benchmark positional coordinates were obtained for each plot using an Omni Model 1000 Total Station surveying transit. Sample locations were taken along the inside boundary of the berm, at equal distances within each plot, and at the bottom and top of each flume (Figure 2.4). The survey coordinates were entered into ArcView via the Enter Points by Coordinates extension. The coordinate data were then geo-referenced by way of the benchmark coordinates, and interpolated to a 1-meter grid by way of the "Interpolate Grid" option under the "Surface" menu. These interpolations create individual DEMs for each pasture plot and were named

Pasture1_dem, Pasture2_dem, etc. and saved in their respective project

4_ArcView_Datasets\grid directories.

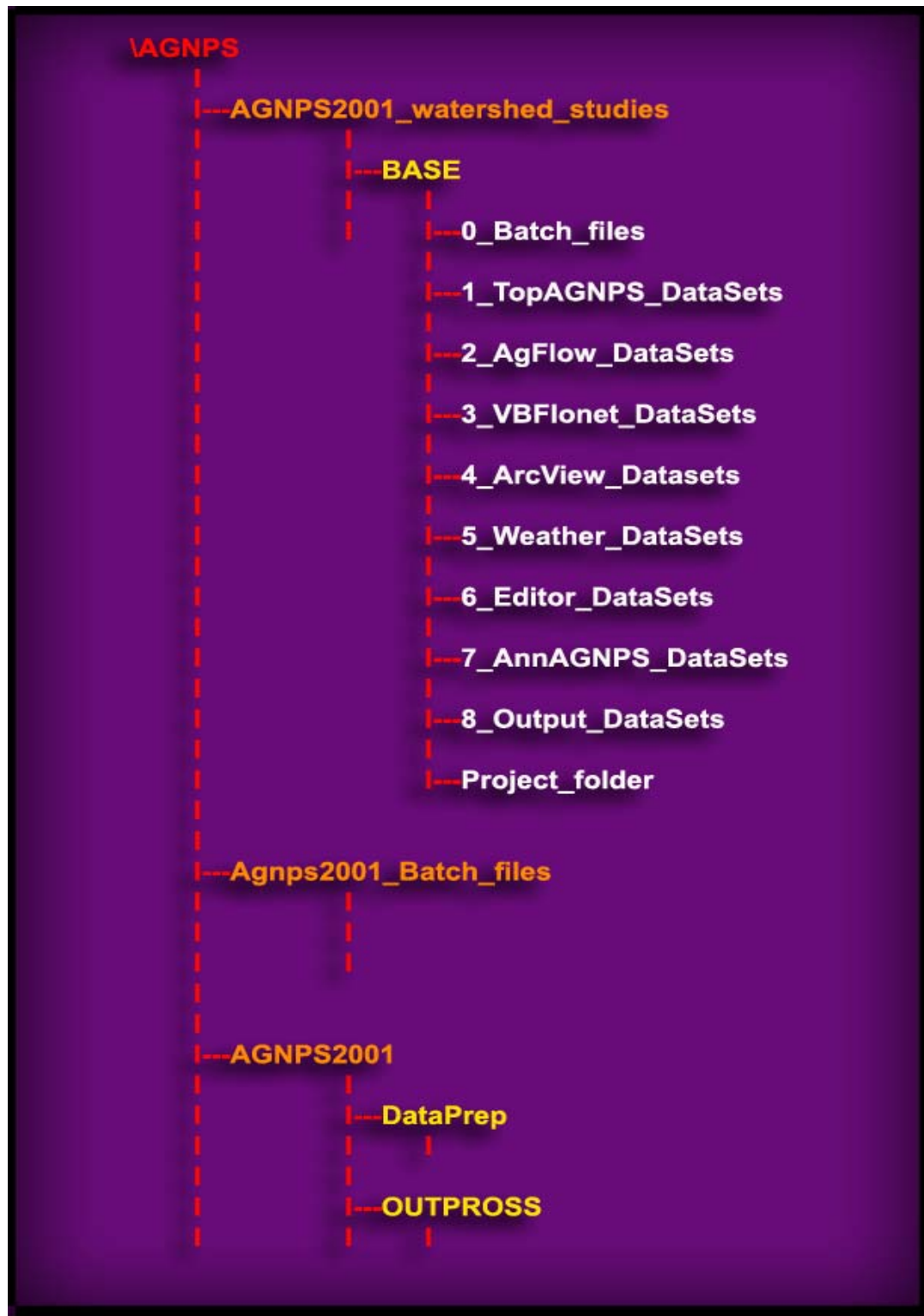


Figure 2.2. General AnnAGNPS file structure tree.

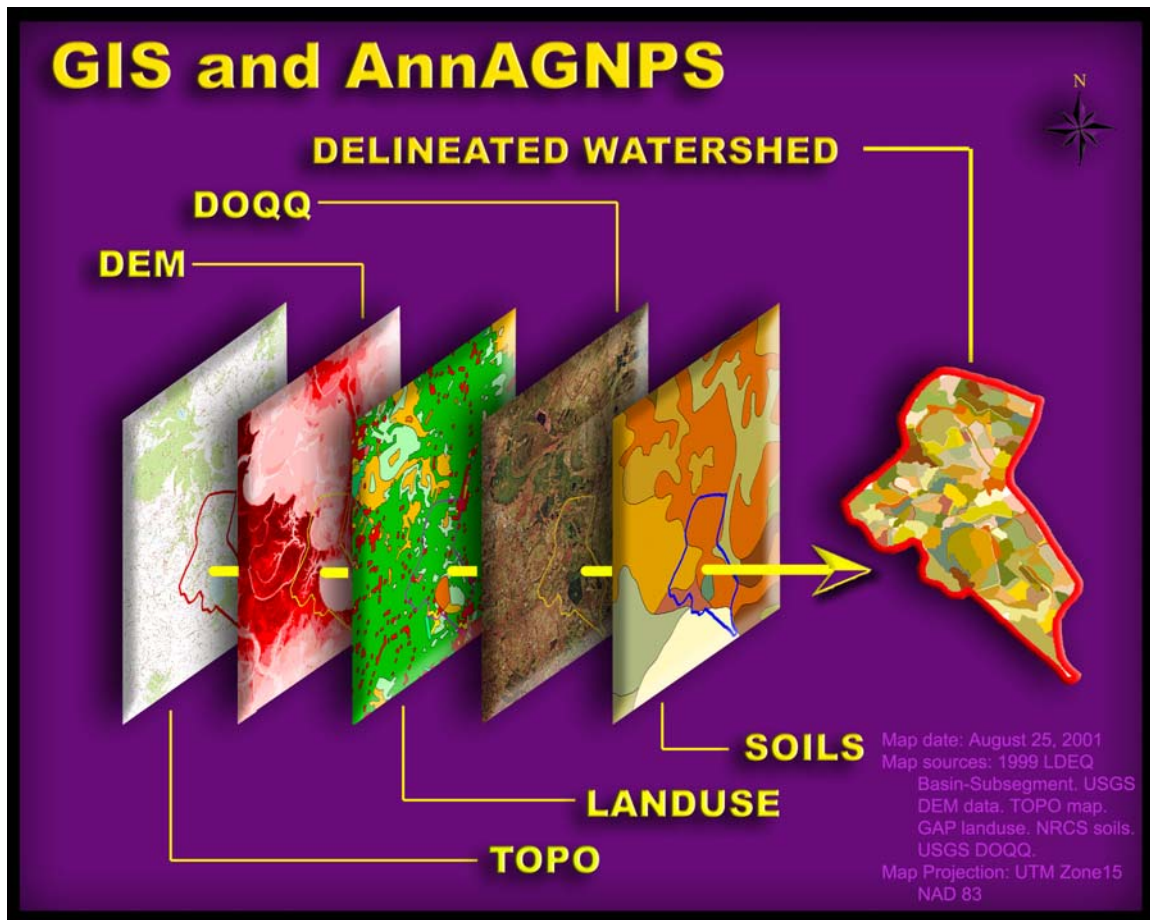


Figure 2.3. Major datasets required for AnnAGNPS watershed delineation and Non-Point Source pollution predictions

For each plot, the earthen berm was created within the DEM by selecting the "New Theme" option from the "View" menu, creating a shapefile in the polygon feature type, and saving as a Pasture*_Berm file within the 4_ArcView_Datasets\shapefiles directory. With a Pasture*_DEM theme active, the "Draw Polygon" button was selected from the toolbar. With the coordinate points theme overlaid upon the DEM theme, the points corresponding to the inside of the earthen berm were used to draw a polygon depicting the inner edge of the berm. An additional polygon was drawn to depict the outer edge of the berm. With both polygons selected, the "Combine Features" option was selected from under the "Edit" menu. With the Pasture*_Berm theme active, the "Open

Them Table" button was select from the toolbar and the ID value changed by using the "Edit" button. The ID value was made greater than the largest elevation value within the Pasture*_DEM file. Edits were saved and stopped, and the Pasture*_berm shapefile converted to grid by selected the "Convert To Grid" option from under the "Theme" menu. The resulting file was saved as Pasture*_Berm, stored in the project 4_ArcView_Datasets\grids directory, received an output grid extent the same as Pasture*_berm, an output grid cell size the same as the DEM file, and the ID field for cell value. With the Pasture*_berm grid file active, the Grid Analyst Extension was used to "Merge" the berm and DEM grid files together.

Finally, with the Pasture*_DEM theme active, and the Single Cell Editor extension loaded, the raster values for the portion of the berm that crosses the flume outlet were reduced to match the nearby landscape elevation values. This was done by selecting the "Single Cell" button from the toolbar, clicking the DEM's raster cell to be changed, and selecting the raster cells new value from within the value matrix. A path and filename for saving was specified before selecting the "create new grid theme" button. At this point the field-scale delineation DEM preprocessing was complete. The TopAGNPS and AGFlow sections should be completed prior to model simulation.

2.3 TOPAGNPS/AGFLOW

The AnnAGNPS model uses the AnnAGNPS Flownet Generator to extract data from the preprocessed project DEM file. The Flownet Generator consists of two key modules TopAGNPS (Garbrecht and Martz, 1995) and AGFlow (Bingner and Theurer, 2001). The first module is Topographic AGNPS (TopAGNPS), which is an assemblage of the Digital Elevation Drainage Network Model (DEDNM), Raster Processing

(RASPRO), and Raster Formatting (RASFOR) executables files. The TopAGNPS executables are controlled using a set of TopAGNPS input files. These files, which are all stored in the project 1_TopAGNPS_DataSets directory, consist of the DNMCNT.inp, DEDNM.inp, RASFOR.inp, RASPRO.inp, and NTGCOD.inp files. The second module is AGFlow, a Fortran coded program used to generate the DEM related input parameters. The AGFlow executable file is controlled using the FLOWGEN.inp file. The TopAGNPS/AGFlow files either exist as sequential, formatted, ASCII, or can be created using an ASCII text editor.

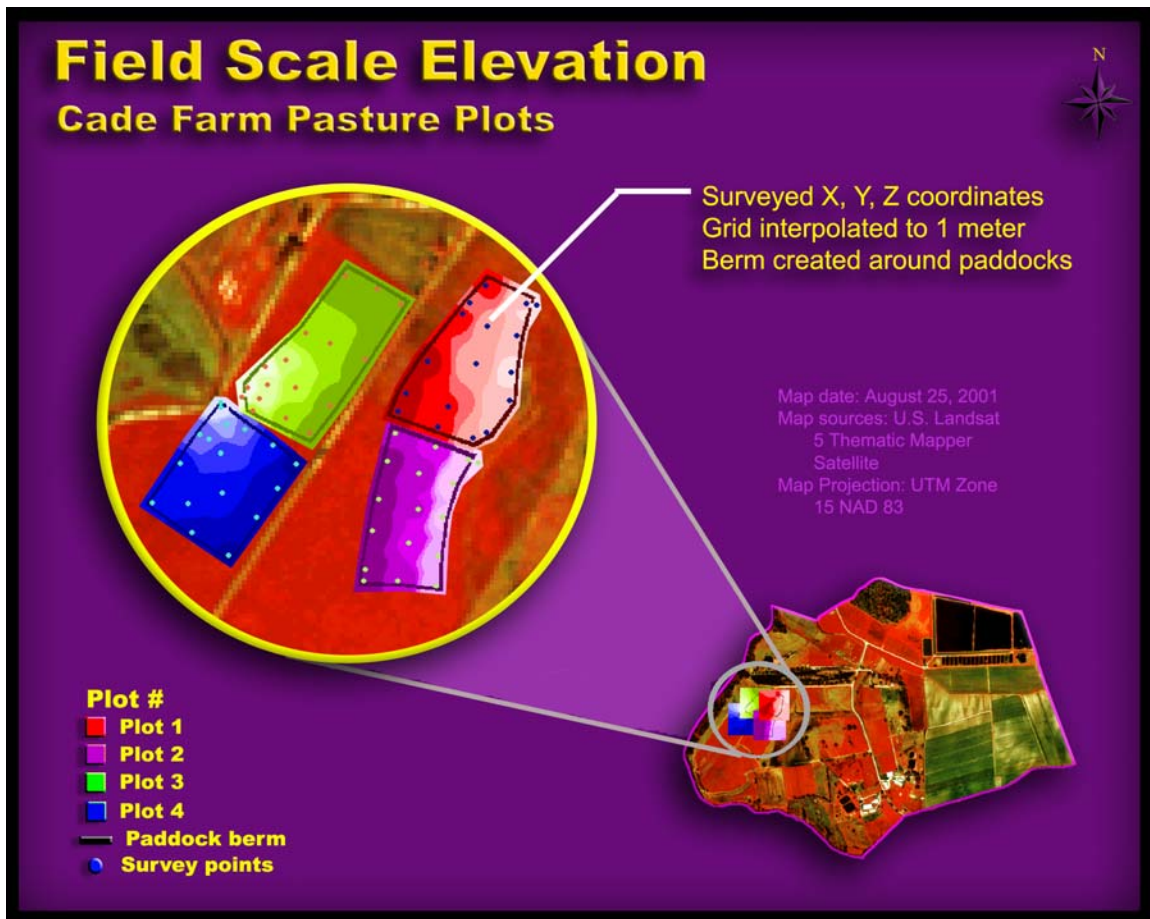


Figure 2.4. Interpolated Digital Elevation Models from field-scale plot, berm and flume elevation data

2.3.1 TopAGNPS Input Preparation

Generating the BASE_DEDNM.inp file requires proper reformatting, converting, and placement of the preprocessed DEM file. This DEM conversion process reformats the DEM grid file into an ASCII format, converts the file from Arc format to the TopAGNPS format by removing all header information and storing the elevation data in a single continuous column, and saves the resulting file in the TopAGNPS datasets directory. As a time-saving measure, the author configured an Avenue script that integrates ArcView's formatting capability with AnnAGNPS' Arc conversion program. This script, Asci2dednm (Appendix A), can be copied into a text editing program and saved as an *.AVE file in the ArcView script directory.

With the ArcView project window active, the "Script" button was selected. The "Load Text File" button was then selected, and the Asci2dednm.ave script was loaded, compiled, and run. This script can also be added to a toolbar button, allowing for its initialization from within the ArcView project window and facilitating its use (Figure 2.5). With the ASCII Raster file type selected within the export file type drop box, the final DEM file was located, and a new file named xport1.asc was saved into the project 1_TopAGNPS_DataSets directory. From within the 9_execute_convARC executable window (which was initialized by the script) the ArcView to TopAGNPS conversion was selected by typing the number 2, and pressing the enter key. The path and filename of the file to be converted, and the resulting conversion must be specified. Since the xport1.asc file was saved into the same directory as the CONV_ARC executable, the following path and filenames were used, .\xport1.asc, and .\xport2.asc. The DEM number of rows and columns, size of raster cell, and northing and easting information

were displayed. This information is vital to accurate TopAGNPS and AGFlow execution and should be noted for later use. The enter key was pressed, and the final ArcView to TopAGNPS conversion was performed. The script then converted the xport2.asc filename and type to the TopAGNPS required BASE_DEDNM.inp.

The DNMCNT input file is described in the AnnAGNPS Input Data Preparation Model Technical Reference (Bingner et al., 2001) as a file which contains parameters describing the characteristics of the DEM raster, DEM resampling and network extraction parameters, and user output options. The DNMCNT.inp file, which was edited using a text editor, requires the following DEM raster parameters: UTM zone, UTM northing and easting, number of columns and rows and the length of square raster cells. If this information was not documented during the DEDNM file processing, it can be obtained by reading the header information found in the xport1.asc file. The DEM's outlet column and row coordinates must also be provided. This information can be extracted from the DEM by using the ArcView Cell Tool extension, which was obtained from the ESRI internet script page. With the extension loaded in ArcView, the "Row and Column" tool was used to select the DEM's outlet raster cell. It should be noted that the Cell Tool extension only works when the geographic projections of the world projection is active within ArcView. The Critical Source Area (CSA) and Minimum Source Channel Length (MSCL) source codes, which are user-defined parameters that account for spatial variability using various combinations of cell area and channel length, are critical DNMCNT input parameters. A CSA/MSCL code must be assigned for each DEM raster cell (elevation) value within the NTGCOD.inp file. Values of 52 hectares for CSA, and 60 meters for MSCL were used during conventional delineations, and 50 hectares and 60

meters, respectively, for artificial delineations. Default values were used for the aggregation, re-sampling, smoothing, calibration, error checking and output option parameters.

The NTGCOD.inp file is a code file, that designates user specifications regarding CSA and MSCL. It is required that each DEM raster cell (elevation) value be assigned a CSA-MSCL code. Multiplying the number of DEM columns by the number of rows calculates the number of CSA-MSCL codes that must be used. A text editor was used to create the NTGCOD.inp file, which contains a single column consisting of 278,464 rows, and receiving the CSA-MSCL code of "1".

RASPRO is a general input file that allows the user to select additional processing options for DEDNM generated raster files. Specific parameter names and functions include, options to output report file, process network and sub-catchment data, process elevation data, number of elevation classes desired, computation of local slope and aspect alternatives, and computation of flow path distances. Values of "1", which enables an option, were used for all parameters except for the number of bands of equal elevations parameter which received a value of "30".

The RASFOR input file is a parameter file that regulates the conversion of unformatted DEDNM and RASPRO files into a format usable in subsequent processing. Specific parameter names and functions include, output format options, create report file, options to write desired output, options to reformatting for files produced by DEDNM, and options to reformatting for files produced by RASPRO. Since the output from two output formats is desired, it is necessary to create two RASFOR input files. The first RASFOR file is the BASE_RASFOR.inp file, which receives a format value of "0" and

contributes to the generation of the AnnAGNPS Cell, Reach, and Subarea output text files. The second RASFOR file is the BASE_RASFOR_ARC.inp file, which receives a format value of "3" and results in the generation of ArcView formatted output files. The remaining output values within both the RASFOR.inp and RASFOR_ARC.inp files are user-specific and should be chosen based on output needs.

2.3.2 AGFlow Input Preparation

The AGFlow executable file is used during the delineation process to generate various cell, reach, and sub-area input data. This process requires the FLOWGEN.inp file, which contains user selected paths to the input and output files required by the AGFlow executable. The DEM raster cell size, number of rows and columns, and outlet column and row location, are additional FLOWGEN.inp file requirements.

2.3.3 TopAGNPS/AGFlow Execution

An Avenue encoded script, named TOPAG.ave, was created to assist in the initialization of the 1_execute_TopAGNPS batch file. This batch file has been encoded to rename all BASE_*.inp files to the required *.inp format, initialize all TopAGNPS and AGFlow executables files, relocate essential files, and delete unnecessary files. The TOPAG Avenue script can be assigned to a toolbar button, allowing for its initialization from within the ArcView project window (Figure 2.5).

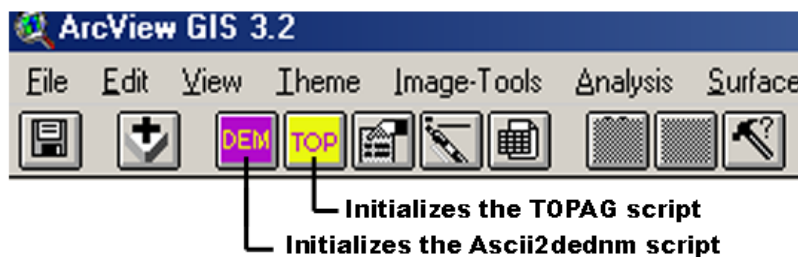


Figure 2.5. ArcView integrated Topag and Ascii2dednm script toolbar buttons

The TOPAG script button was selected, activating the 1_execute_TopAGNPS batch file. The batch file begins by copying and renaming the BASE_*.inp to the required *.inp format. The DEDNM program is then initialized and the following processes are executed: DEM input and DEM pre-processing, depression and flat area treatment, flow vector, flow path and drainage area computations, channel network definition, and watershed outlet and boundary definition. Next, DEDNM displays a matrix showing the drainage area outlet and defining row and column numbers of the stream network immediately upstream from the outlet. Values are assigned to each column and row location indicating contributions from upstream areas. If the outlet location is accurate, the number "1" should be entered to proceed with the remaining DEDNM processes. However, in the event that an inaccurate outlet location was specified, the number "0" should be entered and the matrix values should be used to search the watershed matrix for the accurate outlet row and column location. Channel link and network node computation, catchment computation, and creation of unformatted files are all done before the DEDNM program is terminated. The DEDNM window was closed, and pressing any key in the Batch window initializes the RASPRO program.

The RASPRO program executes the following processes: depression and flat area definition, local slope and aspect computations, network and boundary enhancement computation, flow path distance computation, and creation of the control file SBRT IOCNT. The program then undergoes a normal program termination and the window should be closed.

Pressing any key in the batch window results in the initialization of the RASFOR program. This is the first of two executions by the RASFOR program, and results in the

generation of the Cell, Reach, and Subarea ASCII files. The program generates the following output files before undergoing a normal program termination: INELEV, FILDEP, RELIEF, FLOVEC, FLOPAT, UPAREA, NTGCOD, NETFUL, BOUND, NETW, SUBWTA, TSLOPE, TASPEC, and DISOUT.

After closing the RASFOR window, pressing any key begins the first run of the AGFLOW program. The AGFLOW program runs several subroutines, using the FLOWGEN input data and several TopAGNPS output files to create previously specified ASCII output data and report files. Pressing any key after program termination copies and renames the RASFOR_ARC.inp file to the required RASFOR.inp format.

The second runs of both the RASFOR and AGFLOW programs create the user specified ARC formatted output files. The Batch file then places the ASCII output files in the BASE\2_AgFlow_DataSets directory, the CELL.arc and STREAM.arc formatted files in the BASE\4_ArcView_Datasets\covers directory, and the BOUND.arc, DISOUT.arc, FLOVEC.arc, NTGCOD.arc, TASPEC.arc, TSLOPE.arc, and UPAREA.arc formatted files in the BASE\4_ArcView_Datasets\grids directory.

2.3.4 TopAGNPS/AGFlow Output

The files generated by the TopAGNPS and AGFlow programs should be opened, viewed, and/or converted as needed. The two files of immediate concern are the CELL and STREAM Arc formatted files. These files should be opened and whether the outlet, AOI, and size of cells are accurate and meet the user's specification determined. From within the Base ArcView project, the "Import Data Source" function was selected from under the "File" menu. The ASCII Raster file type was selected, and the BASE\4_ArcView_Datasets\covers directory is located using the browse feature in the

Import Raster file window. Selecting All files (*.*) from the file type drop box revealed the CELL.arc and STREAM.arc files. The files were highlighted, the import function accepted, and the files were converted to grid files and again saved as CELL and STREAM files in the BASE\4_ArcView_Datasets\covers directory. The files were then added to the project with cell values as integers, and the data were displayed as unique cell number values, (these settings were selected by double-clicking the chosen theme's legend, then selecting unique values from the legend type drop-box and values from the values field drop-box). The CELL and STREAM data were then overlaid upon the Topo maps and reach themes to assess the accuracy of the delineated cells, reaches, and outlet location. If results are unsatisfactory, the outlet's column and row location, CSA-MSCL codes, and additional input files can be adjusted and the delineation process repeated. Otherwise, the AnnAGNPS CELL.asc and REACH.asc output files were then opened using an ASCII text editing program, and examined for any gross computational errors.

2.4 INPUT EDITOR

AnnAGNPS pollutant loading simulations require a series of input source and climate data. These data are stored within the AnnAGNPS.inp and DayClim.inp files, and are used to describe watershed components and establish simulation period parameters. There are 33 data categories that comprise the AnnAGNPS.inp file (Table 1.1). Each category contains a series of parameters and variables. The feedlot, field pond, gully, impoundment, irrigation, point source and strip crop data are non-essential categories of AnnAGNPS and were not used during the farm-scale delineation and simulation study. The AnnAGNPS.inp and DayClim.inp files can be created, edited and converted using the Windows based AGNPS2001 Input Editor (Bingner et al., 1998), and

Generation of weather Elements for Multiple applications (GEM; Johnson et al., 2000) weather generator programs.

2.4.1 Input Data

A new session of the Input Editor, which was opened from within the project 6_Editor_DataSets directory, must be started before the creating or modifying of input data is possible. The "New AnnAGNPS file" option from under the "File" menu was used to create this new session. Selecting the "Open Existing AnnAGNPS file" option from the same menu allows for the loading of a previously existing input file. A third option, "ReOpen Last Session", loads the previously initiated session. The Input Editor was used to create and edit input data in the recommended order specified in Table 1.1. Each data window within the Input Editor must be "Accepted" before the input file can be saved. It is important to note that accepting the changes made in any Input Editor window does not save the data, but only loads it into Random Access Memory (RAM), making it available to be saved from within the Main Input Editor window. The Input Editor contains a "Help" option, which contains descriptions and ranges of acceptable values for each data field. Each data field name may be used as a toggle to activate or deactivate help fields.

The File Identifier section of the AnnAGNPS input data consist of the AnnAGNPS Identifier and the Watershed Data categories. The AnnAGNPS Identifier data is used to give as brief description of the watershed and its name and location. The AnnAGNPS Identifier data is also used to specify input and output units, and operation mode desired for the simulation process. The operation mode options include, AnnAGNPS for continuous simulation and AGNPS for single event simulation. The

Watershed Dataset is identical to and generated from the AnnAGNPS Identifier dataset. The USGS sub-segment data, and the EPA Surf Your Watershed internet site (<http://www.epa.gov/surf/>) were sources used for obtaining the required File Identifier information.

The Simulation Period Data consist of simulation begin and end data, the rainfall distribution code, rainfall factor, 10 year EI, irrigation climate code, soil moisture steps, erosion model code, annual K-factor code, variable K-factor code, number of initialization years, and default reach geometry. A simulation period of 30 years, from January 1, 2001 to December 31, 2031, was chosen for Cade farm simulations. The following sources were used to obtain or generate pertinent Simulation Period data: <http://www.lmnoeng.com/RainfallMaps/RainfallMaps.htm> for rainfall distribution maps, isoerodent map and soil-erodibility monograph (Troeh et al., Reference, 1999) for rainfall factor and annual K-factor, and the RUSLE USDA Agriculture Handbook (Renard et al., 1997) for 10 year energy intensity and EI number. The precipitation N and daily precipitation simulation period parameters, and non-cropland global initialization defaults, where not used in this study.

The Cell Related Data section consists of the Cell Data and Cell Profile Data categories. The Cell Data corresponds largely to the Flownet Generator Cell input file, which consists of the number of cells, cell identifier, cell soil identifier, cell field identifier, cell reach identifier, reach location code, cell area, cell time of concentration, cell average elevation, cell average land slope, cell aspect, RUSLE 'ls' factor, sheet flow Manning's 'n', sheet flow slope, sheet flow length, shallow concentrated flow slope, shallow concentrated flow length, concentrated flow slope, concentrated flow length,

concentrated flow bottom width, concentrated flow side slope, concentrated flow hydraulic depth, and concentrated flow Manning's 'n'. The majority of these parameters were loaded using the "Import" function under the "File" menu of the Input Editor's main window. The Cell input file import option was used to update current cell data, and convert system units. The following sources were used to obtain and/or generate the remaining pertinent Cell data: digital soils data for cell soil identifier, and digital landuse data for cell field identifier. Digital soils data was created by scanning the detailed soils map from the St. Martin parish soil survey. The scanned image was added to the ArcView project, the Image Georeferencing Tool extension was used to rubber-sheet, and relocate the scanned image until it was aligned with the DOQQ, Topo map and reach data. A new polygon theme was created, and the "Draw Polygon" button used to trace each soil series polygon to create a digitized version of the detailed soils map. The "Snap" function, which is located within the "Editing" option under the "Function Properties" menu, was adjusted for edge-matching of conjoined polygons (FIGURE 2.6). The delineated cells theme was then overlaid on top of the detailed digitized soils theme to determine dominant soil series within each cell.

The Field Related Data section consists of the Field Data, Field Management Data, Operations Data, Operations Reference Data, Contour Data, Irrigation Application Data, Fertilizer Application Data, Pesticide Application Data and the Strip Crop Data categories. The following were deemed pertinent Field and Field Management Data parameters and variables for this project, and the remaining parameters are either non-functioning components of AnnAGNPS, or were non-essential: field identification, field landuse identifier, field manage identifier, rotation years, percent rock cover, RUSLE sub

P factor, inter-rill erosion code, and random roughness. Digital landuse data and land operator records were used to determine field, landuse and management identifiers, rotation years, and the Field Management sequence data.

The Operations and Operations Reference datasets contain all fertilizer, pesticide, irrigation, crop and non-crop sequential information, as well as related field operations data. The Operations data was obtained from historical farming data, land operator records, and field observations. The Reference dataset used was obtained from LaDEQ's water quality monitoring department, and each operation was adjusted as needed to more accurately depict field conditions. The Fertilizer Application, Pesticide Application Datasets, and the Contour Dataset, which contains fertilizer, pesticide, and slope and ridge height information, respectively, were obtained from land operator records and field observations. The Irrigation Application and Strip Crop Datasets, which contain identifying, and sequence and date information, were not applicable.

The Reach Related Data section consists of the Reach Data, Reach Geometry Coefficients, Reach Nutrient Half-life, and the Impoundment Data. As with the Flownet Generator Cell input data, the Reach input data was "imported" into the Reach portion of the AnnAGNPS.inp file. For simulation simplification, default reach geometry was used for the Reach Geometry Coefficients, and the non-essential Reach Nutrient Half-life parameters were ignored. Since there were no major impoundments within the study area, the Impoundment Data were not used.

The Other Component Data section consists of the Feedlot Data, Feedlot Management Data, Gully Data, and the Point Source Data. Other Component Data, may be determined from field observations, stream samples and land operator records. For

simulation simplification, the Other Component Data parameters were deemed non-essential and not used in this project.

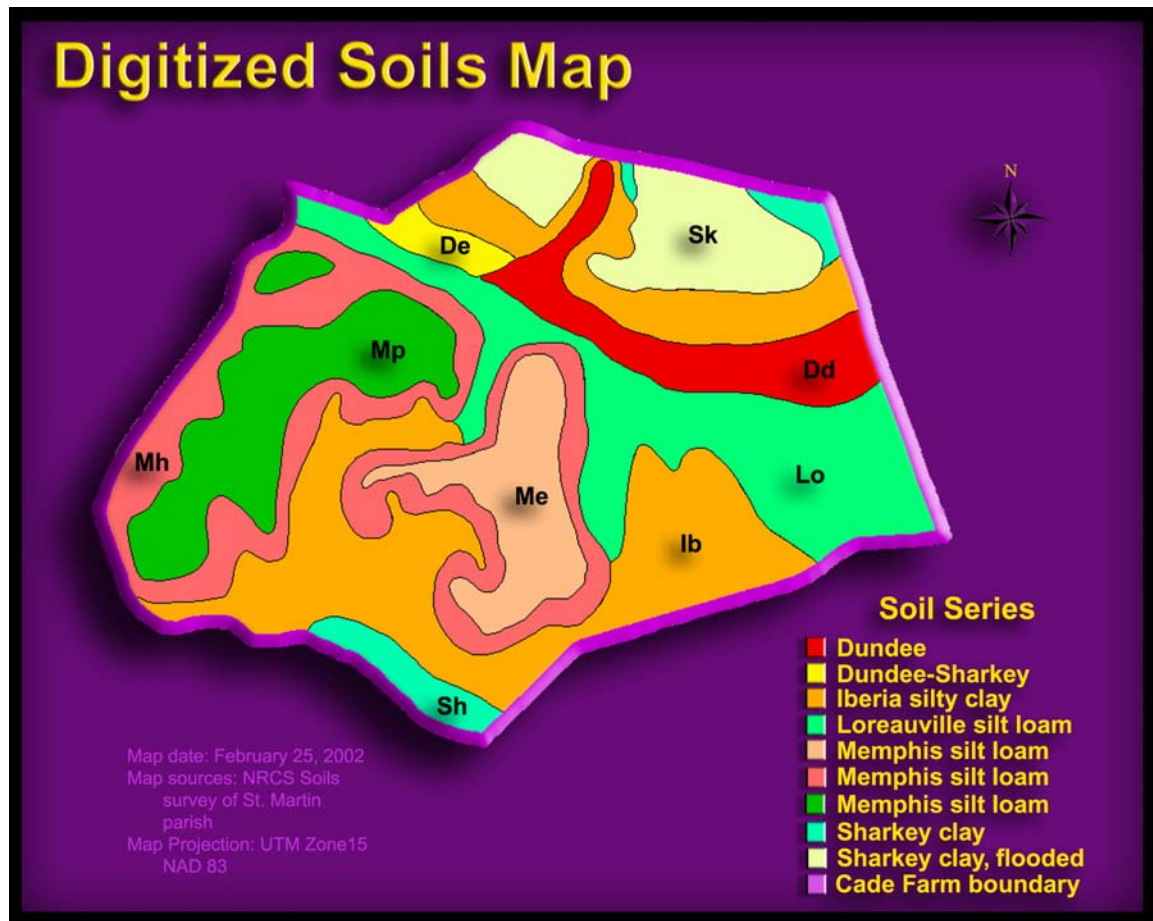


Figure 2.6. Cade Farm digitized soils map.

The Reference Data section consists of the Crop Data, Fertilizer Reference Data, Landuse Reference Data, Pesticide Reference Data, Runoff Curve Number Data, and Soil Data. The Crop Data consist of a list of current crops and related harvest and pre-harvest characteristics. They were obtained from field samples/analysis and from detailed land operator records. The Fertilizer Reference and Pesticide Reference Datasets were obtained from LaDEQ but are preferably obtained from land operator records and

individual product application rates and label information. The Landuse Reference Dataset consists of root mass, cover ratio, rainfall height and surface residue cover for all non-crop landuses. It was compiled using field observations and the land operator records. The Runoff Curve Number reference data file was obtained from the official National Sedimentation Laboratory's AnnAGNPS website, and used to determine curve numbers for all specific cover types, treatments and hydrologic conditions within the study area.

The Soils Dataset contains soil identifier, hydrologic soil group, K-factor, albedo, time to consolidation, impervious depth, specific gravity, soil name, soil texture data, layer depth, bulk density, and the following layer specific data: clay, silt, clay, rock, and very fine sand ratios, calcium carbonate, saturation conductivity, field capacity, wilting point, volcanic code, base saturation, unstable aggregate ratio, pH, organic matter, organic N, inorganic N, organic P, inorganic P ratios and soil structure code. The majority of the soils parameters and variables were obtained from the Natural Resources Conservation Service (NRCS) soil characterization

<http://vmhost.cdp.state.ne.us:96/SERIS.HTML> and National MUIR database

<http://www.statlab.iastate.edu/cgi-bin/dmuir.cgi> sites. Other sources of soils data are

NRCS parish soil surveys and the Louisiana NRCS digital soils data

<http://www.la.nrcs.usda.gov/Soils-GIS/soilsgis.htm> and an online soil texture triangle

hydraulic properties calculator located at

<http://www.bsyse.wsu.edu/saxton/soilwater/#PWP>.

The Output Related Data section is made up of the Global Output Specification, Reach Output Specification, Source Accounting Output Specification, and the

Verification Datasets. The values and parameters for this section were all determined using the user's output file and data specifications.

It is critical to "Accept" all Input Editor windows after completing a data entry session. The final AnnAGNPS.inp file was saved to the project

7_AnnAGNPS_DataSets.

2.4.2 Climate Data

The Climate Data required by the AnnAGNPS model consist of a time series of daily precipitation, maximum and minimum temperature, dew point temperature, percent sky cover, and wind speed. These datasets were assembled using historically gathered and synthetically generated data. Historical data was obtained from the National Oceanic and Atmospheric Administration's (NOAA's) National Climatic Data Center (NCDC) internet site <http://lwf.ncdc.noaa.gov/oa/ncdc.html>, and from climatic summaries and data atlases.

The Generation of weather Elements for Multiple applications (GEM; Johnson et al., 2000) weather generator model was used in conjunction with AnnAGNPS to generate synthetic weather data. The GEM model generated daily precipitation, maximum and minimum temperatures, and solar radiation, and was used in conjunction with daily dew point temperature, sky cover, and wind speed to create the final Climate Data file. Steps for creating this file are as follows:

The Windows Explorer was used to open the GEM.exe file located in the AGNPS2001\DataPrep\Weather\GEM\Execute directory. GEM then prompts answers for the following questions: Do you want to view the name list of available stations? The letter "Y" was typed and a list of available weather stations were made viewable

(Typing "N" allows the user to select stations based on latitude and longitude). The Lafayette, Louisiana station was selected, and those positioned within 100 miles of that location were chosen (those not desired may be excluded before proceeding). GEM allows the user to supply average annual precipitation (if known, step bypassed if not) for weather data calculations and probability estimations. AnnAGNPS requires a time series of weather data. 30 years of weather was specified (the default value is 10 years). The default value was selected by pressing the "enter" key for the remaining questions. These questions pertain to random process seed, English units for output data, and write to the default GEM_out.inp. The generated weather file, GEM_out.inp, is not formatted for use by, nor contains all data required by the AnnAGNPS file.

In addition to the GEM_out input file information, the model requires monthly average sky cover, dew point temperature, and wind speed. These data were obtained from a climatic data atlas and climatic summary of the AOI. A text editor was used to generate a file titled MonClim.inp, and saved to the AGNPS2001\DataPrep\Weather\Climate\Datasets directory. An example of this file (located in the Climate\Datasets directory) was used as a guide for proper formatting of the MonClim.inp file. This input file was used in conjunction with the GEM_out.inp file to create the AnnAGNPS required DayClim.inp file.

With the GEM_out.inp and MonClim.inp files created, activating the Complete_Climate.bat file initiates the Complete_Climate.exe file. This executable file generates the daily dew point temperature, sky cover and wind speed information, then creates and formats the DayClim.inp file containing the six required daily climatic elements. An additional climatic parameter must be supplied if the cell time of

concentration is not provided for all Cell Data Identifiers within the AnnAGNPS.inp file. This parameter is the 2 year 24 hour precipitation data and can be determined using an Eastern U.S. Precipitation Frequency Map obtainable from the following NCDC internet site <http://www.nws.noaa.gov/er/hq/Tp40s.htm>. The 2 year 24 hour precipitation data must be entered using the Input Editor. From the Main window of the Input Editor, the "Input → Daily Climate Data File" function should be selected, and the DayClim.inp file chosen from the project...\Climate\Datasets directory. Once the Daily Climate Data window is loaded, entering the 2 year 24 hours parameter in the first record updates that entry for all records. Changes to the Daily Climate File should then be "Accepted", and the DayClim.inp file should be saved to the project 7_AnnAGNPS_DataSets directory.

2.5 ANNAGNPS SIMULATION

The AnnAGNPS and DayClim input files are the only mandatory data files required for AnnAGNPS model simulations. However, a third optional file may be used to specify different file names for the AnnAGNPS.inp and DayClim.inp files. This feature is useful if numerous input and climate scenarios are to be simulated in a rapid fashion.

The Windows Explorer was used to open the 7_execute_AnnAGNPS.bat file located in the C:\AGNPS\Agnps2001_Batch_files directory. This batch file removes any old input files contained within the BASE\7_AnnAGNPS_DataSets directory, copies the AnnAGNPS.inp and DayClim.inp files to the BASE\7_AnnAGNPS_DataSets directory, and initiates the AnnAGNPS.exe model program. As detailed in the AGNPS Input Data Preparation Model Technical Reference, the model consists of three general elements, data preparation, simulation processing and source accounting (Bingner et al., 2001).

Data preparation consists of preprocessing of the watershed and synthetic climate data for reach area, reach routing order, reach geometry, soil layer, RUSLE, time period checks and cell time of concentration computations. The simulation process entails processing information involving cells, feedlots, gullies, point sources, and reaches. Finally the source accounting output calculates accumulations of pollutants for user defined watershed components (cells, feedlots, gullies, point sources, or reaches). The final step in the model execution was to create the AnnAGNPS.dbg, AnnAGNPS.evn, and AnnAGNPS.src files, and place them in the BASE\7_AnnAGNPS_DataSets directory.

In addition to the three source accounting output files listed above, a fourth file (AnnAGNPS.err) may be created by the model if errors are encountered during model execution. If errors are detected during the error checking processes, the AnnAGNPS executable file is terminated and the AnnAGNPS.err file generated. The errors, (such as missing data and values outside of the acceptable range) are detailed within the AnnAGNPS.err file using message statements that define the source of error.

2.6 OUTPUT PROCESSING

The AnnAGNPS suite of programs includes the Output Processor, which enables the user to convert the raw data generated by the model into a tabular formatted file that includes table headings and data summaries. The Windows Explorer was used to open the 8_execute_Output_Tables.bat file located in the C:\AGNPS\Agnps2001_Batch_files directory. This batch file copies the AnnAGNPS.evn and AnnAGNPS.src files from the BASE\7_AnnAGNPS_DataSets to the BASE\8_Output_DataSets directory, and initiates the OutPut.exe model. The OutPut model organizes the event and source accounting information based on user specifications such as water, sediment class, sediment source,

nitrogen, pesticide, and phosphorus. The resulting Base_SA.dat and Base_EV.dat files were stored in the BASE\8_Output_DataSets directory and viewed using most text editing software.

As with the AnnAGNPS model, the Output Processing model creates an error file if errors are observed during the error checking processes. These errors, which include missing data, values outside of the acceptable range, and inaccurate header information, are detailed within the Output_Tables.err file using message statements that define the source of error.

2.7 RESULTS AND DISCUSSION

2.7.1 Farm-scale Delineations

The objective of the farm-scale delineation process was to create or modify DEM data to accurately represent observed field conditions and generate representative hydrologic cells and reaches. Topo maps, DOQQ's, land-use records and observed drainage outlets were the datasets used to determine appropriate size of generated cells. Contour draping, the process of overlaying digital imagery over exaggerated DEM data, was an additional method used for this project. The Erdas Imagine contour drape fly-by function allows the user to move into virtual space to examine three-dimensional elevations, drainage paths and potential hydrologic cells. Figure 2.7, an image of the Cade farm fly-by, was used to determine that six cells would be required to accurately simulate drainage, land-use and soils. Farm and field-scale delineations and predictions were performed using an un-calibrated model, and results are lower than typical output.

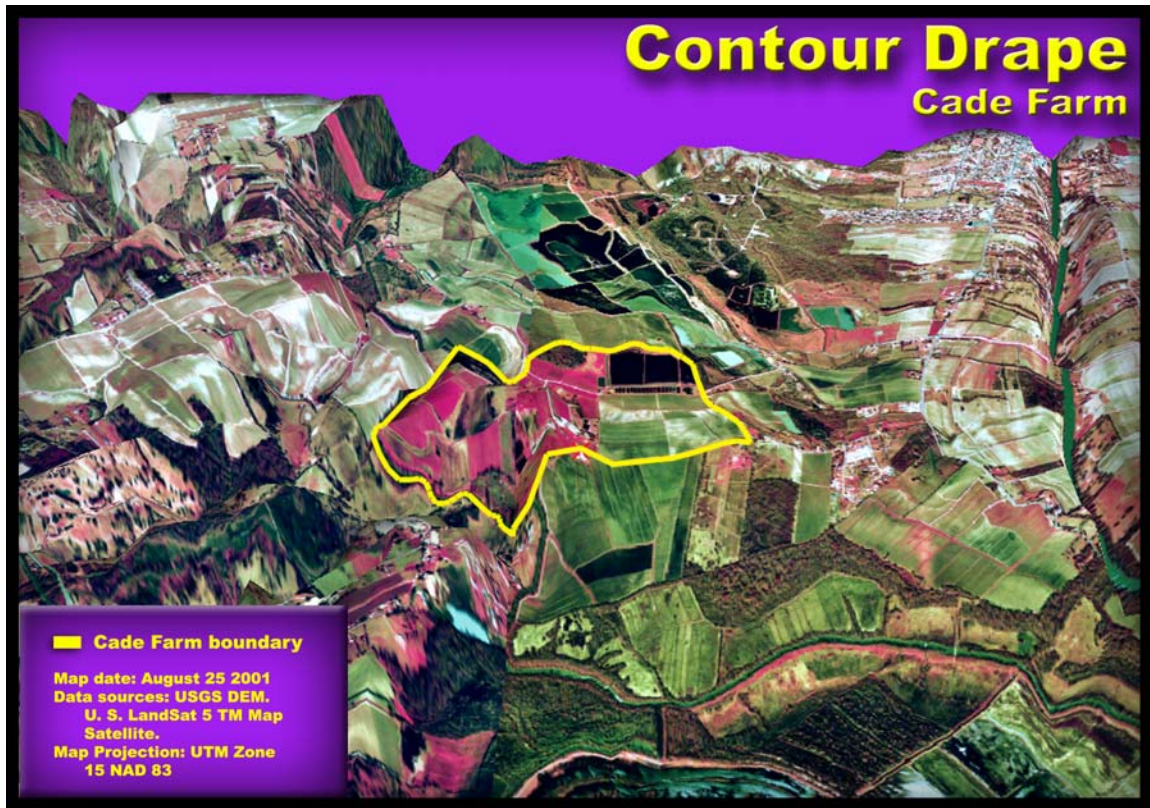


Figure 2.7. Contour drape of the Cade Farm providing flow path and drainage detail.

2.7.1.1 Conventional Delineations

Figure 2.8 depicts the conventional delineation results for the Spanish Lake sub-segment. The CSA and MSCL numbers were adjusted until expected delineation results were achieved. The final conventional delineation produced 173 cells, of which six were wholly or partially contained within the Cade farm boundary. Two were source cells that were assigned cell identifier numbers of 681 and 701, and four were reach cells that were assigned cell identifier numbers of 303, 403, 463 and 683. The conventional delineation process produced 71 reaches, of which four were receiving reaches that bordered the Cade farm, and the fifth was a receiving reach of cell 701 and was located beyond the Cade farm AOI. These reaches were assigned reach identifier numbers, 30, 40, 46, 68,

and 70, respectively. The conventional delineations were used as the standard by which the artificial delineation results were evaluated.

2.7.1.2 Artificial Delineations

Figure 2.9 depicts the artificial delineation results for the Cade farm AOI. CSA and MSCL numbers were adjusted for each delineation run until the results resembled those of conventional delineations. The final artificial delineation produced 41 cells, of which six were wholly or partially contained within the Cade farm boundary. Of the six cells, two were source cells that were assigned cell identifier numbers of 151 and 171, and four were reach cells that were assigned cell identifier numbers of 33, 53, 93 and 153. The artificial delineation process produced 18 reaches, of which four were receiving reaches that bordered the Cade farm, and the fifth was a receiving reach of cell 171 that was located beyond the Cade farm AOI. These reaches were assigned reach identifier numbers, 3, 5, 9, 15 and 17 respectively.

2.7.1.3 Delineation Comparison

Figure 2.10 shows the paired cells for the conventional and artificial delineations. It is evident that the delineation process produced cells with similar area, location and arrangement within the Cade AOI. Cells produced are identified as artificial and conventional delineated pairs numbered 33 and 303, 53 and 403, 93 and 463, 151 and 681, 153 and 683, and 171 and 701, respectively. Prior to the simulation process, ArcView was used to overlay the conventional and artificial delineations to assess location, arrangement and area of paired cells.

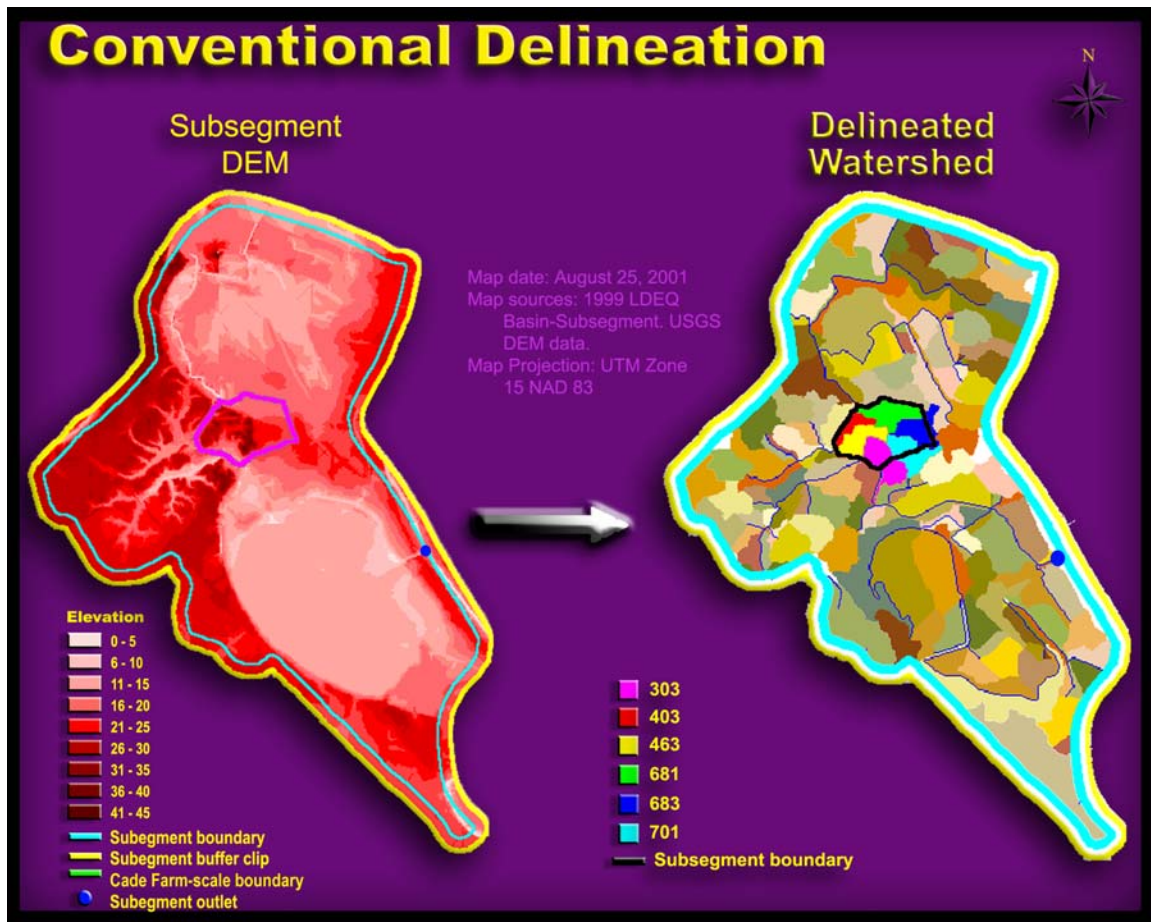


Figure 2.8. Conventional delineations using the Spanish Lake sub-watershed boundary.

2.7.2 Farm-scale predictions

2.7.2.1 Conventional

Using standard input data, AnnAGNPS predicted source accounting and event output data for the conventionally delineated Spanish Lake sub-segment. Table 2.1 gives the area and 30-year mean sediment source accounting predictions for the six Cade cells. Cell size is presented in hectares, and ranges from a low of 28.79 ha for cell 463, to a high of 71.72 ha for cell 303. Sediment source accounting data consist of landscape erosion, landscape sediment yield, and sediment loading. Landscape erosion is the total sediment detached from a cell, landscape sediment yield is sediment that has been

transported and deposited to the landscape and sediment yield is sediment that has been detached, transported and deposited into a waterbody. Due to low sediment values, predicted data for the pasture cells (303, 403 and 463) are presented in kilogram per year, where sediment data for the non-pasture cells (681, 683 and 701) are presented in kilogram per hectare per year. Predicted landscape erosion ranged from 15.69 to 1078.25 kg/ha yr⁻¹ for the non-pasture land-use cells, and all cells containing pasture systems had 2.72 kg yr⁻¹ of sediment eroded. The range of landscape sediment yield predicted for pasture cells was 0.91 to 1.81 kg yr⁻¹, and from 6.73 to 336.25 kg/ha yr⁻¹ for non-pasture cells. Predicted sediment loading ranged from 0.91 to 1.81 kg yr⁻¹ for the pasture system cells and 6.73 to 288.73 kg/ha yr⁻¹ for non-pasture cells. Affects of pasture land-use systems for cells 303, 403, and 463 resulted in expectedly low predicted sediment erosion and yield, the forest land-use of cell 683 produced mid-range sediment predictions and the cropping land-use systems for cells 681 and 701 resulted in high predicted sediment erosion and yield.

Table 2.2 gives the 30-year average nutrient source accounting predictions for the six Cade Farm cells. Nutrient source accounting predicted data consists of attached N, soluble N, attached P and soluble P. The data are presented in average kg of nutrients that enter a reach per runoff event. The nutrient source accounting data follow similar trends observed with the sediment data, where cells 303, 403 and 463 produced less nutrient runoff than cells 681, 683, and 701. Predicted nutrients ranged from 1.79×10^{-6} to 0.21 kg for attached N, 3.63 to 70.76 kg for soluble N, 1.98×10^{-5} to 0.42 kg for attached P and 13.61 to 67.13 kg for soluble P. These results can be directly attributed to differences in land-cover and fertilizer/management operations.

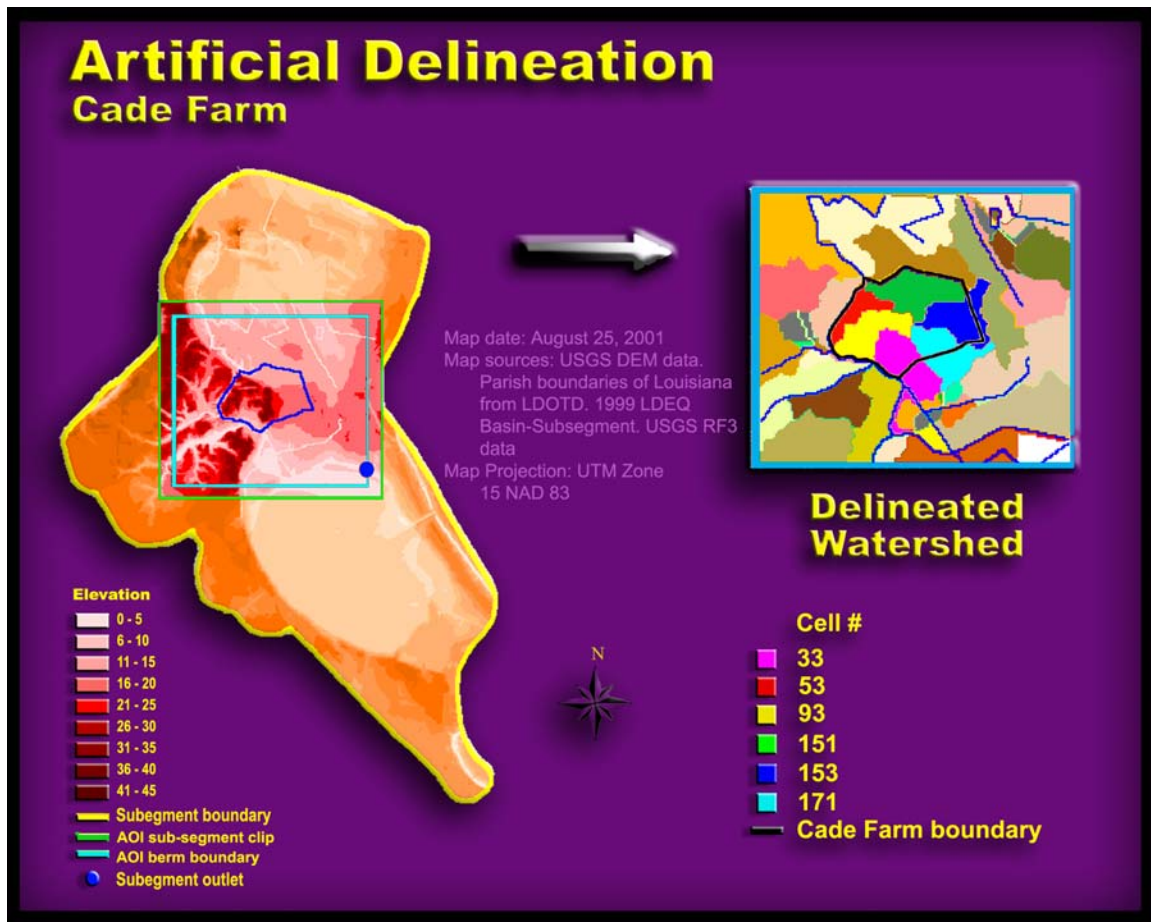


Figure 2.9. Artificial delineations using the Area Of Interest crop and berm method.

2.7.2.2 Artificial

Using standard input data, AnnAGNPS predicted source accounting and event output data for the artificially delineated Cade Farm AOI. Table 2.3 gives the area and 30-year average sediment source accounting predictions for the six Cade Farm cells. Cell size is presented in hectares, and ranges from a low of 28.7 for cell 93, to a high of 72.69 ha for cell 33. Predicted sediment output for the pasture cells is presented in kg per year, while sediment data for cells 151, 153, and 171 is presented in kg per hectare per year. The artificial process predictions exhibit the same landscape erosion, landscape sediment yield and sediment loading data trends as seen with the conventional process predictions.

Predicted landscape erosion ranged from 15.69 to 1064.81 kg/ha yr⁻¹ for the non-pasture land-use cells, and the pasture system cells ranged from 2.72 to 3.63 kg yr⁻¹ of sediment. The range of landscape sediment yield predicted for pasture cells was 0.91 to 1.81 kg yr⁻¹, and from 6.73 to 334.01 kg/ha yr⁻¹ for non-pasture cells. Predicted sediment loading ranged from 0.91 to 1.81 kg yr⁻¹ for the pasture system cells and 6.5 to 243.9 kg/ha yr⁻¹ for non-pasture cells. These results can be attributed to the effects of land-use within the farm.

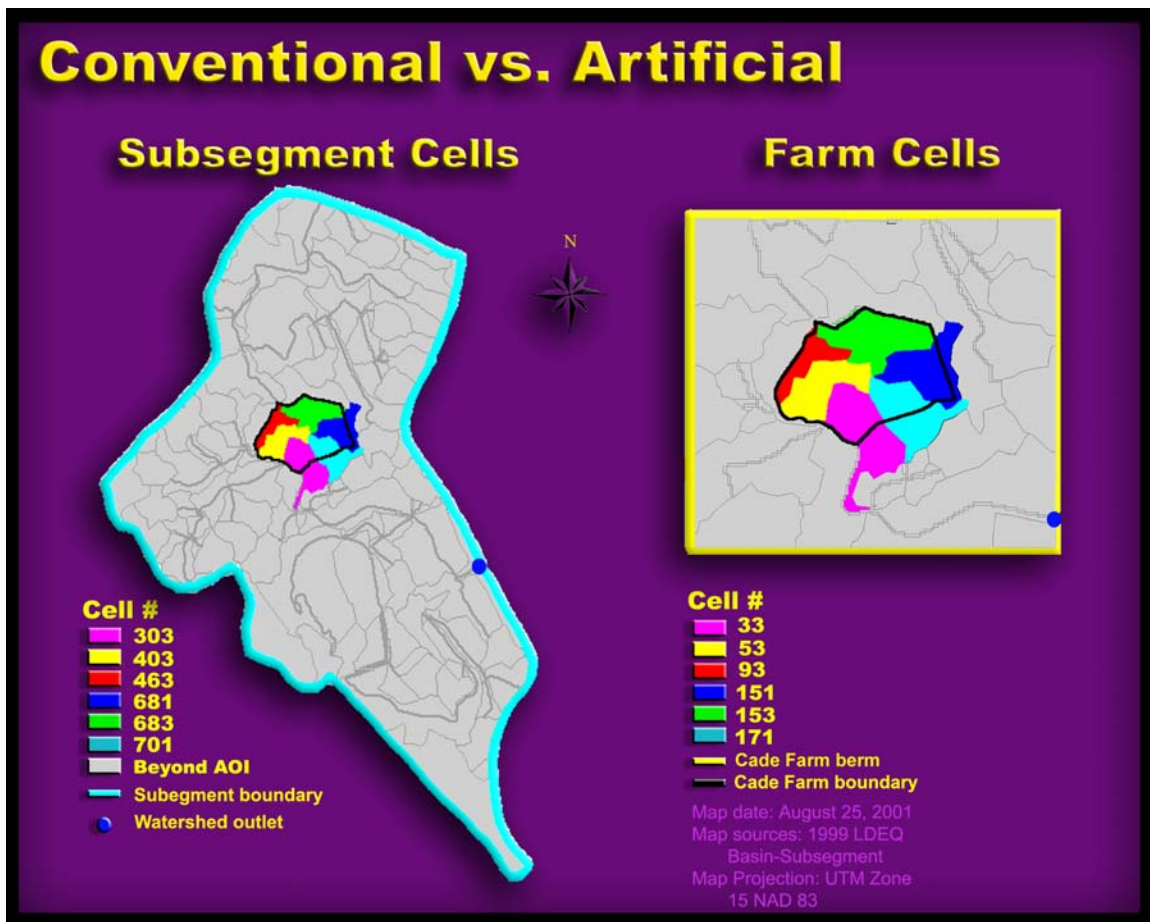


Figure 2.10. Cell size, arrangement and location comparisons of conventional and artificial delineations.

Table 2.1. Cell area and 30-year mean sediment source accounting predictions for farm-scale conventional delineation and simulation.

Cell Identifier	Area (ha)	Landscape erosion	Sediment yield	Sediment loading
303	71.73	2.72 (kg/yr)	1.81 (kg/yr)	1.81 (kg/yr)
403	48.69	2.72 (kg/yr)	0.91 (kg/yr)	0.91 (kg/yr)
463	28.79	2.72 (kg/yr)	1.81 (kg/yr)	1.81 (kg/yr)
681	56.09	1078 (kg/ha/yr)	336.25 (kg/ha/yr)	288.73 (kg/ha/yr)
683	70.01	15.69(kg/ha/yr)	6.73 (kg/ha/yr)	6.73 (kg/ha/yr)
701	59.49	627 (kg/ha/yr)	221.93 (kg/ha/yr)	219.24 (kg/ha/yr)

Table 2.2. Predicted mass of attached nitrogen and phosphorus per runoff for farm-scale conventional simulation.

Cell Identifier	Attached N (kg)	Soluble N (kg)	Attached P (kg)	Soluble P (kg)
303	1.79×10^{-6}	9.07	1.98×10^{-5}	34.47
403	1.28×10^{-5}	45.36	3.08×10^{-5}	39.91
463	2.30×10^{-6}	3.63	2.55×10^{-5}	13.61
681	0.21	60.78	0.42	67.13
683	0.004	70.76	0.01	48.08
701	0.17	68.04	0.36	55.34

Table 2.4 gives the 30-year mean source accounting nutrient predictions for the six Cade Farm cells. Predicted nutrients ranged from 1.91×10^{-6} to 0.19 kg for attached N, 3.63 to 70.76 kg for soluble N, 1.86×10^{-5} to 0.4 kg for attached P and 13.61 to 58.06 kg

for soluble P. These data follow the same trends as the sediment data, where the pasture cells (33, 53 and 93) produced less nutrient runoff than the non-pasture cells (151, 153 and 171). These results can be directly attributed to land-cover and fertilizer/management operations.

Table 2.3. Cell area and 30-year mean sediment source accounting predictions for farm-scale artificial delineation and simulation.

Cell Identifier	Area (ha)	Landscape erosion	Sediment yield	Sediment loading
33	72.69	3.63 (kg/yr)	1.81 (kg/yr)	1.81 (kg/yr)
53	49.21	2.72 (kg/yr)	0.91 (kg/yr)	0.91 (kg/yr)
93	28.7	2.72 (kg/yr)	1.81 (kg/yr)	1.81 (kg/yr)
151	50.11	1065 (kg/ha/yr)	334.12 (kg/ha/yr)	243.9 (kg/ha/yr)
153	69.72	15.69 (kg/ha/yr)	6.73 (kg/ha/yr)	6.5 (kg/ha/yr)
171	59.82	636.6 (kg/ha/yr)	248.83 (kg/ha/yr)	241.43 (kg/ha/yr)

2.7.2.3 Prediction Comparisons

Figure 2.11 compares the delineated area of the conventionally and artificially processed delineated cells. The difference in paired cells range from the smallest of 0.1 ha for cells 93 and 463, to the largest of 3.98 ha for cells 151 and 681. This difference in area for cells 151 and 681 amounts to 7.36% of cell 681's area, and has a 0.613 Poisson analysis z-value of difference. The z-value is a means of assessing the accuracy of the artificially processed predictions based on conventional predictions. The more accurate the predictions, the closer to zero the z-value will be. Where z-values between -2 and 2

are highly agreeable, and values exceeding 3 in absolute value are highly inaccurate (Mendenhall et al., 1999). This difference in area can be attributed to the differences in stream networks generated. Though this difference is minor, it can be corrected by either including a larger portion of the stream network within the artificial delineation or by forcing flow-paths via an additional stream burn-in. The assessment of agreement between artificial and conventional delineations is determined using the R^2 value (coefficient of determination) for cell area of all six Cade Farm cells. The R^2 value for these cells is 0.987761, which indicates a high degree of agreement.

Table 2.4. Predicted mass of attached nitrogen and phosphorus per runoff for farm-scale artificial simulation.

Cell Identifier	Attached N (kg)	Soluble N (kg)	Attached P (kg)	Soluble P (kg)
33	1.91×10^{-6}	9.07	1.86×10^{-5}	35.38
53	1.29×10^{-5}	45.36	3.12×10^{-5}	40.82
93	2.29×10^{-6}	3.63	2.54×10^{-5}	13.61
151	0.18	52.62	0.36	58.06
153	0.004	70.76	0.01	48.08
171	0.19	68.04	0.39	55.34

Figures 2.12 and 2.13 compare the sediment loading between the paired cells. These data have been separated to compensate for the large differences in predicted sediment. This approach groups cells based on predicted sediment loading, resulting in an optimum display of data. Differences in paired cells sediment load range from zero, to

the largest of 44.83 kg/ha yr⁻¹ for cells 151 and 681. This difference in sediment load (for cells 151 and 681) amounts to 15.53% from the standard conventional prediction, and has a 0.041 Poisson analysis z-value. The difference in sediment load predicted for paired cells 151 and 681 can be attributed to the difference in cell area, while the differences between cells 171 and 701 are unknown. The R² value for all paired cells is 0.965795, indicating strong agreement between predicted sediment values.

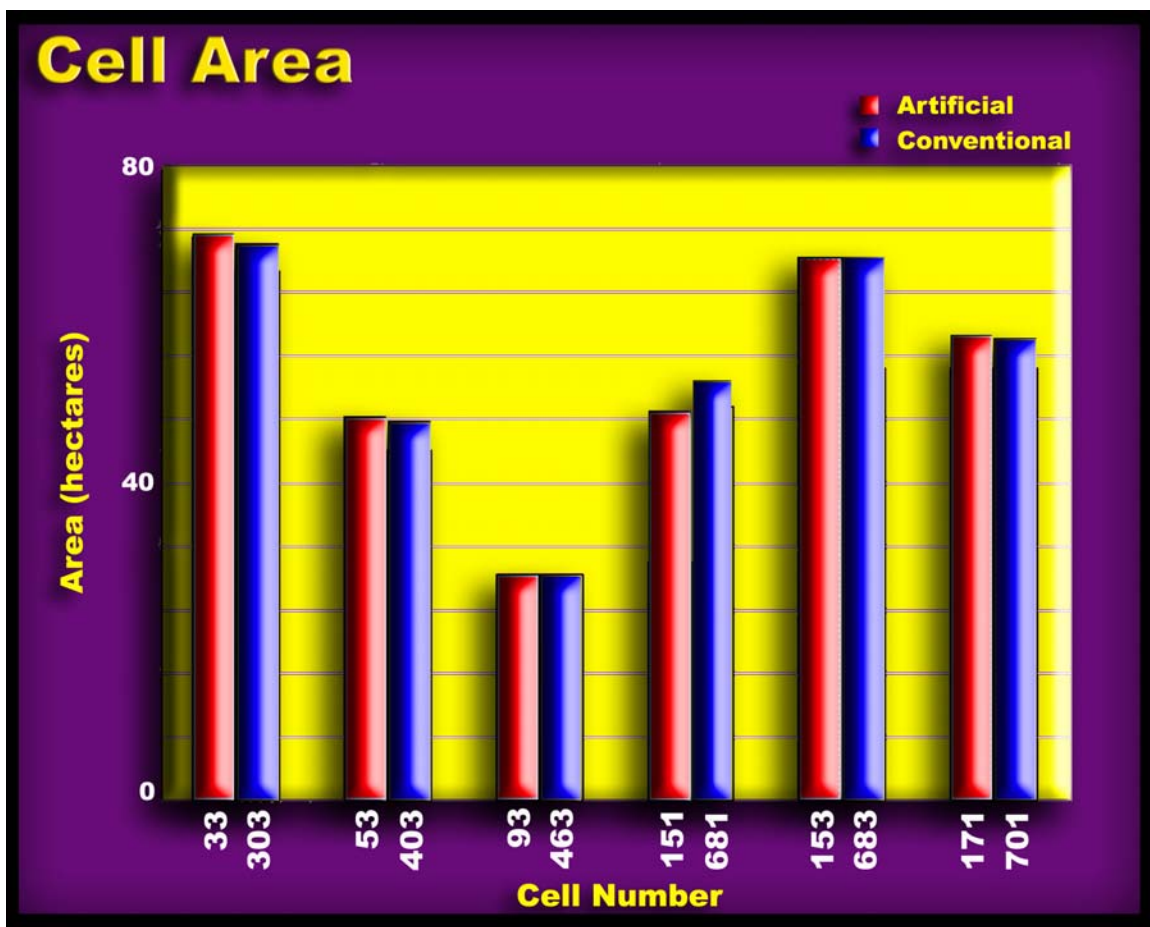


Figure 2.11. Farm-scale conventional and artificial delineation results of cell area.

Figures 2.14, 2.15, 2.16, and 2.17 compare the predicted nutrient loading for paired cells. Figures 2.14 and 2.15 attached nitrogen and phosphorus respectively,

display similar trends to those observed in the non-pasture system sediment loading data. The largest difference observed between paired cells occurs between cells 151 and 681. The difference in predicted attached nitrogen for cells 151 and 681 is 0.03 kg, a percentage difference from standard prediction of 14.83%, and has a 0.002 Poisson analysis z-value. The difference in predicted attached phosphorus for cells 151 and 681 is 0.063 kg, a percentage difference from standard prediction of 14.87%, and a 0.002 Poisson analysis z-value. Figures 2.16 and 2.17 show soluble nitrogen and phosphorus predictions. All paired cells show small differences, cells 151 and 681. Differences in predicted soluble nitrogen for these cells is 8.16 kg, a difference of 13.43%, and a 0.025 z-value. Differences in predicted soluble phosphorus for cells 151 and 681 is 9.07 kg, or 13.51%, and a 0.027 z-value.

2.7.3 Field-scale

Figure 2.18 shows the location of field-scale elevation data gathered for the Cade Farm pasture plots. The figure shows the location of the four pasture plots of interest, the surveyed X, Y, and Z coordinates, digitally constructed berm and interpolated DEM. Interpolation results were examined and repeated until adequate representation of plot topography was achieved. Figure 2.19 shows field-scale delineations for each pasture plot. Where CSA and MSCL values were adjusted to demonstrate the models ability to create various field-scale cell size and reach lengths. Higher CSA and MSCL values resulted in fewer cells and reaches and lower CSA and MSCL values resulted in more cells and reaches created.

2.8 CONCLUSION

An objective of this study was to examine the applicability of the AnnAGNPS pollution model for surface runoff, nutrient loading, and sediment yield predictions for an artificially delineated farm-scale and field-scale watershed. Additional objectives were to establish methods for management-scale watershed delineations, and to create an instructional guide documenting procedures.

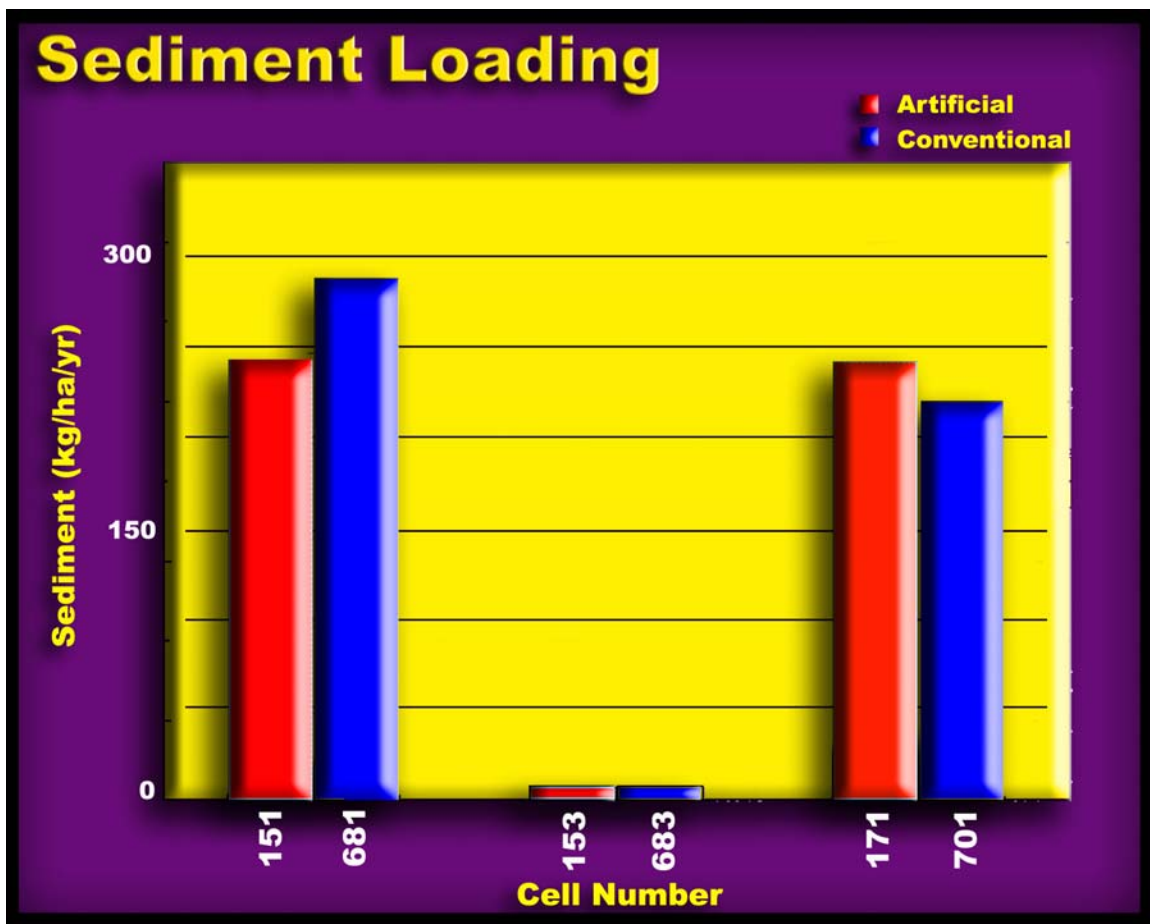


Figure 2.12. Farm-scale conventional and artificial simulation results of sediment load for cells containing pasture system operations.

2.8.1 Farm-scale Delineation Study

The farm-scale delineation study was performed to establish a simple and dependable process for exclusively delineating an AOI. This method should reduce the quantity of data and time required and allow for the gathering, processing and simulating of more accurate site-specific data. Farm-scale simulations should result in more accurate predictions, allowing for improved management of water related resources. The Spanish Lake sub-segment and Cade Farm delineations produced similar cell and stream networks. Statistical comparisons for hydrologic cells obtained from the standard and artificially delineated watershed simulations were computed for runoff producing events. Estimates for area, sediment, N and P loading in paired watershed cells exhibited a high level of agreement. These results indicate that an integrated AnnAGNPS/GIS system can reliably simulate runoff and NPS loadings for artificially delineated watersheds.

2.8.2 Field-scale Delineation Study

A secondary objective of this research was to demonstrate the models ability to delineate a field/research-scale watershed. Conventionally, the AnnAGNPS single cell mode was used to predict small-scale NPS pollution. This single cell approach greatly simplifies the delineation and data acquisition/entry processes, and lacks the vital variability and accuracy required for current precision agriculture and land management. The method assessed in this study showed the models ability to create CSA/MSCL dependent cells and reaches necessary for field-scale NPS pollution predictions.

This report could be used as an instructional guide for operating a water quality model and GIS integrated system. Successful implementation of the farm and field-scale

methods would allow land operators to initiate and/or evaluate small-scale nutrient and resource management plans.

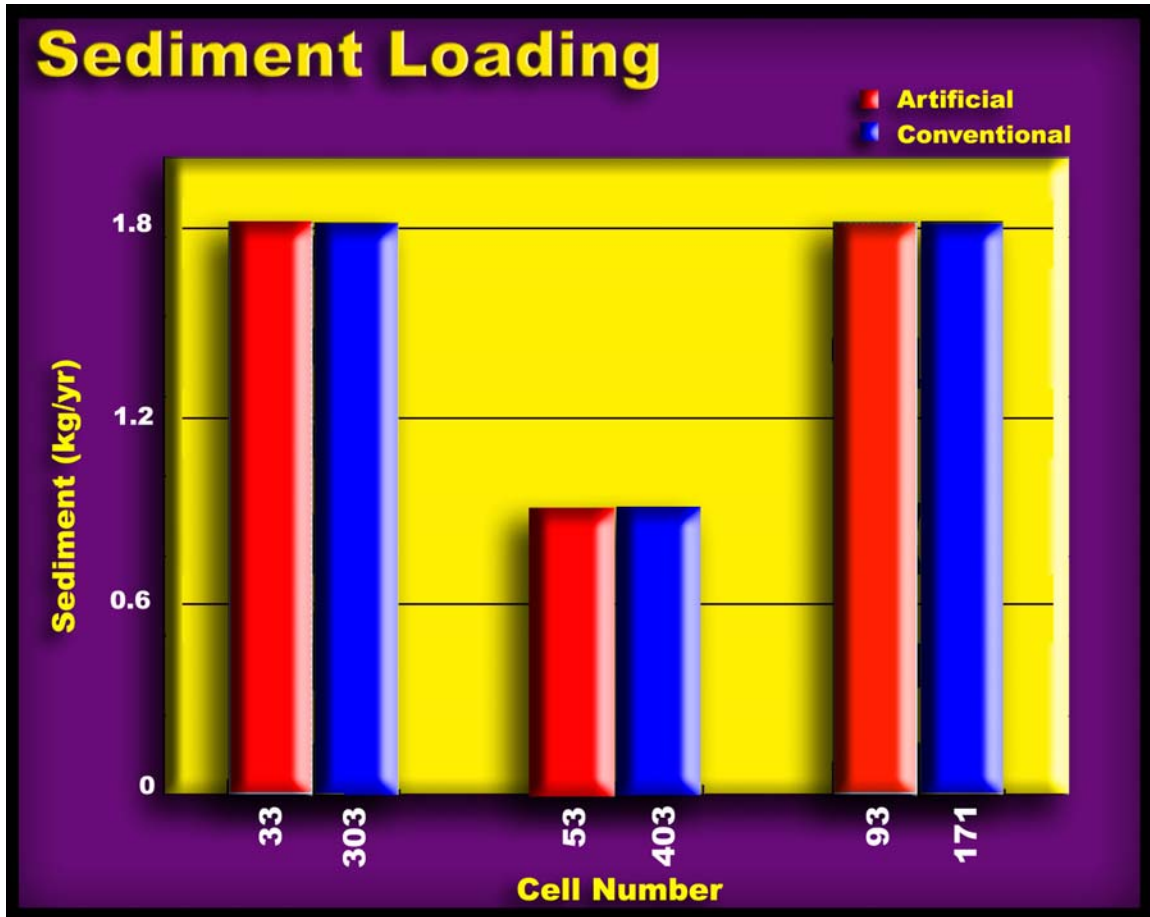


Figure 2.13. Farm-scale conventional and artificial simulation results of sediment load for cells containing non-pasture system operations.

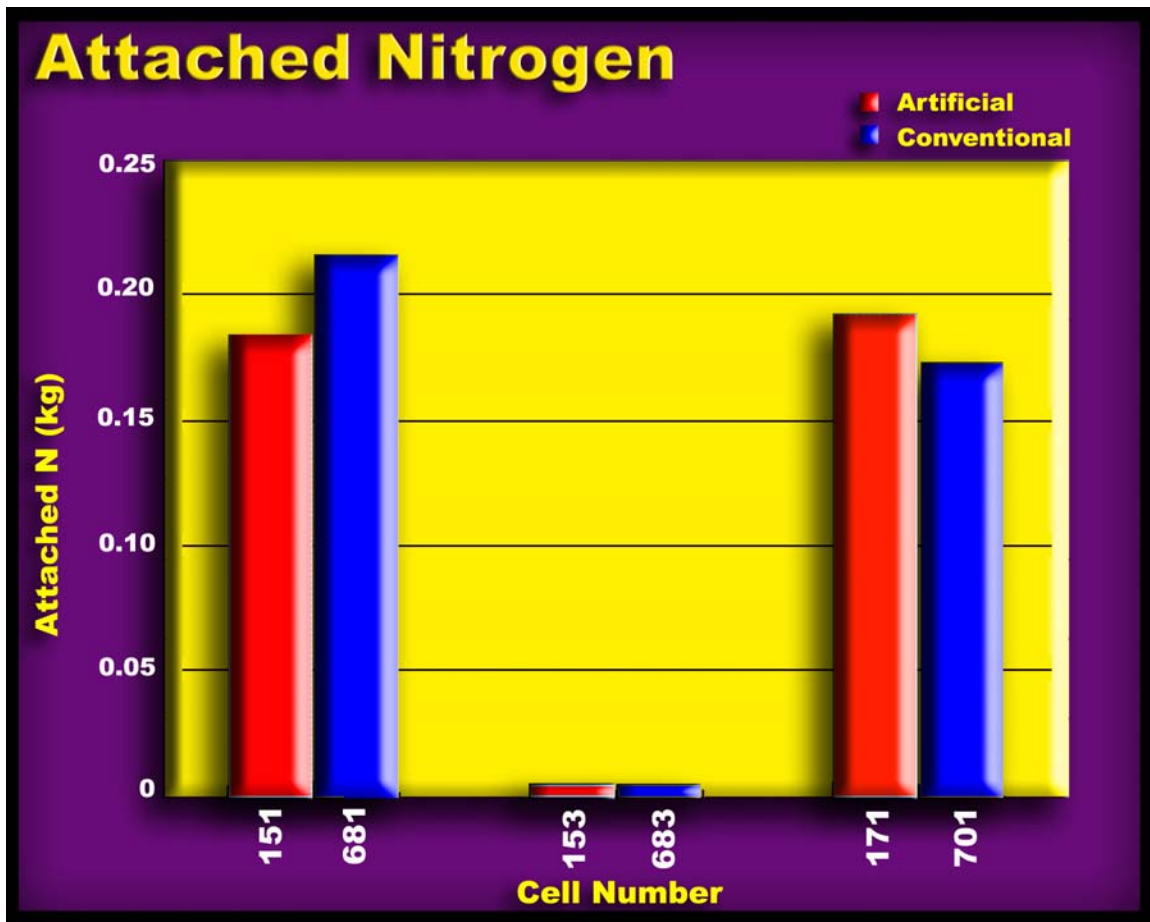


Figure 2.14. Farm-scale conventional and artificial simulation results of attached nitrogen for cells containing non-pasture system operations.

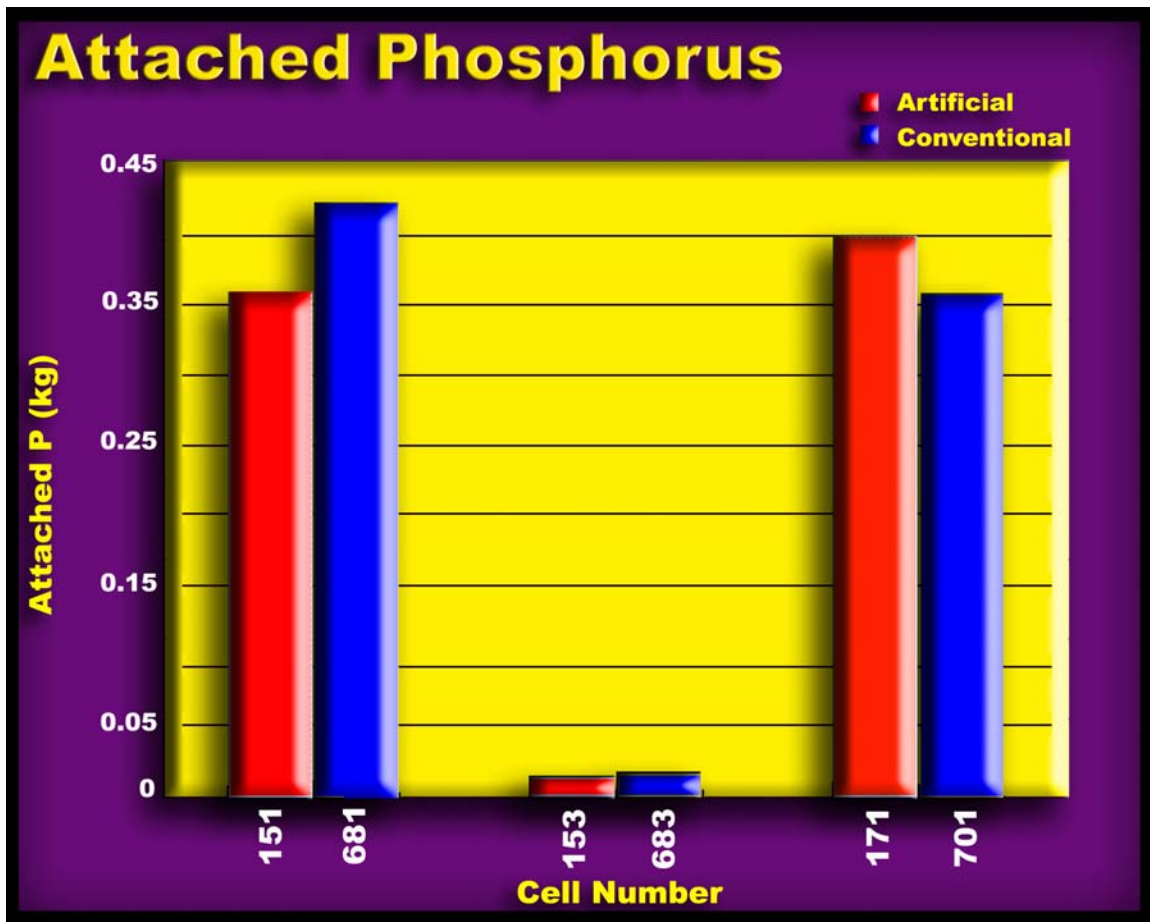


Figure 2.15. Farm-scale conventional and artificial simulation results of attached phosphorus for cells containing non-pasture system operations.

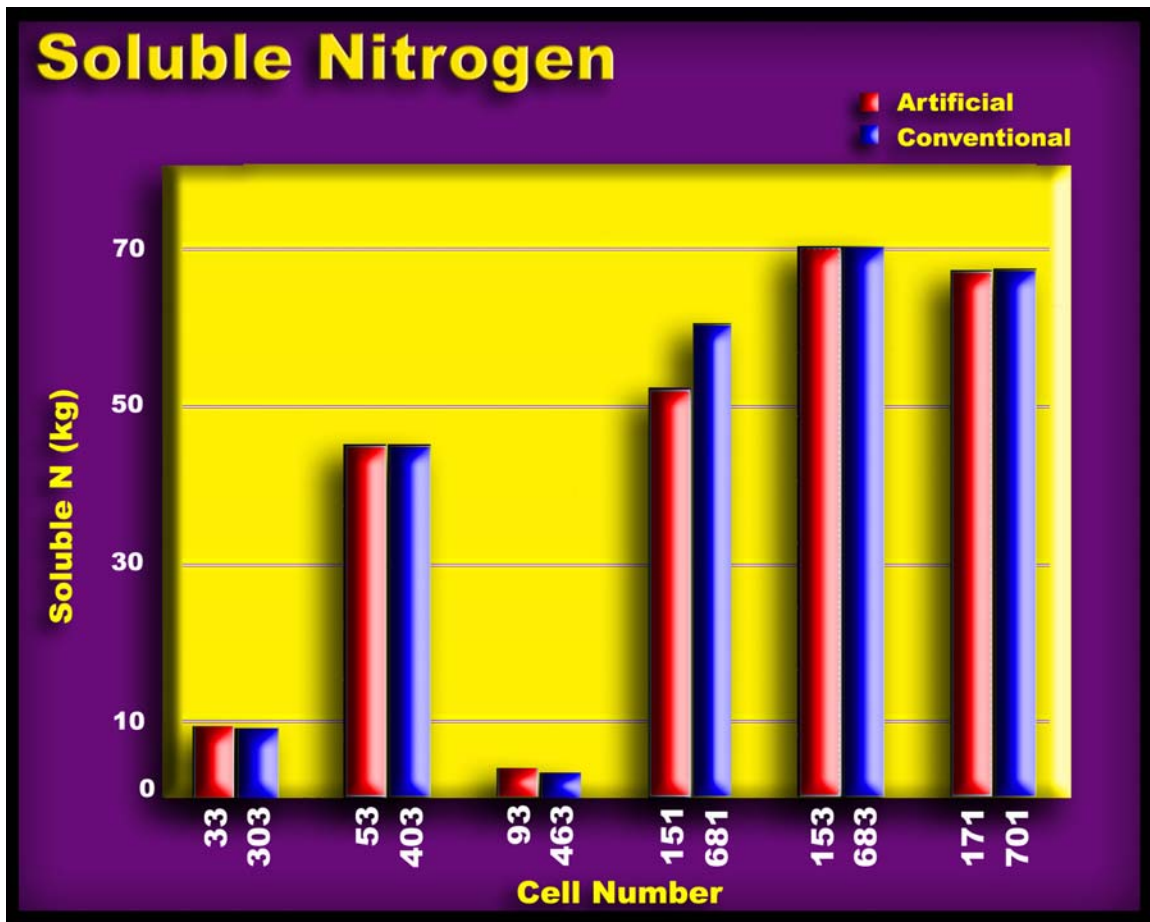


Figure 2.16. Farm-scale conventional and artificial simulation results of soluble nitrogen for Cade Farm cells.

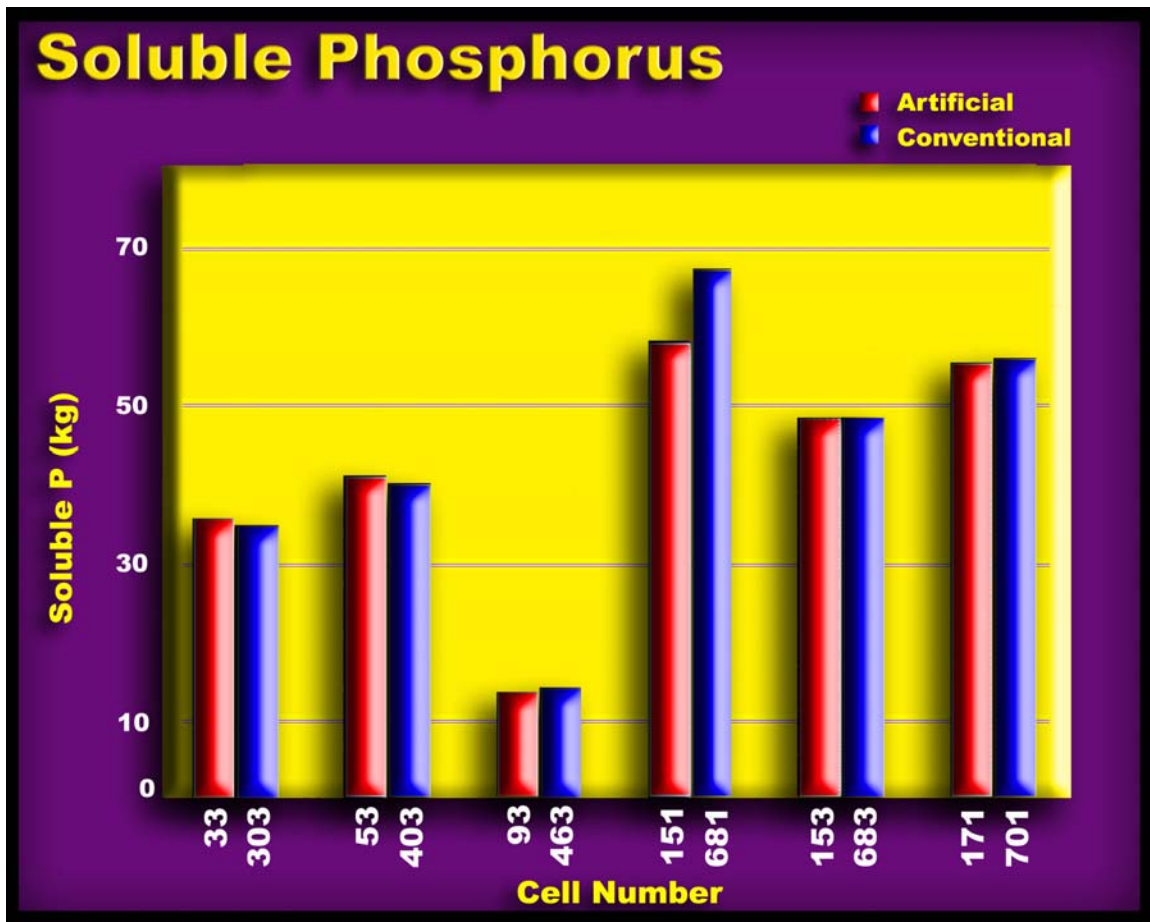


Figure 2.17. Farm-scale conventional and artificial simulation results of soluble phosphorus for Cade Farm cells.

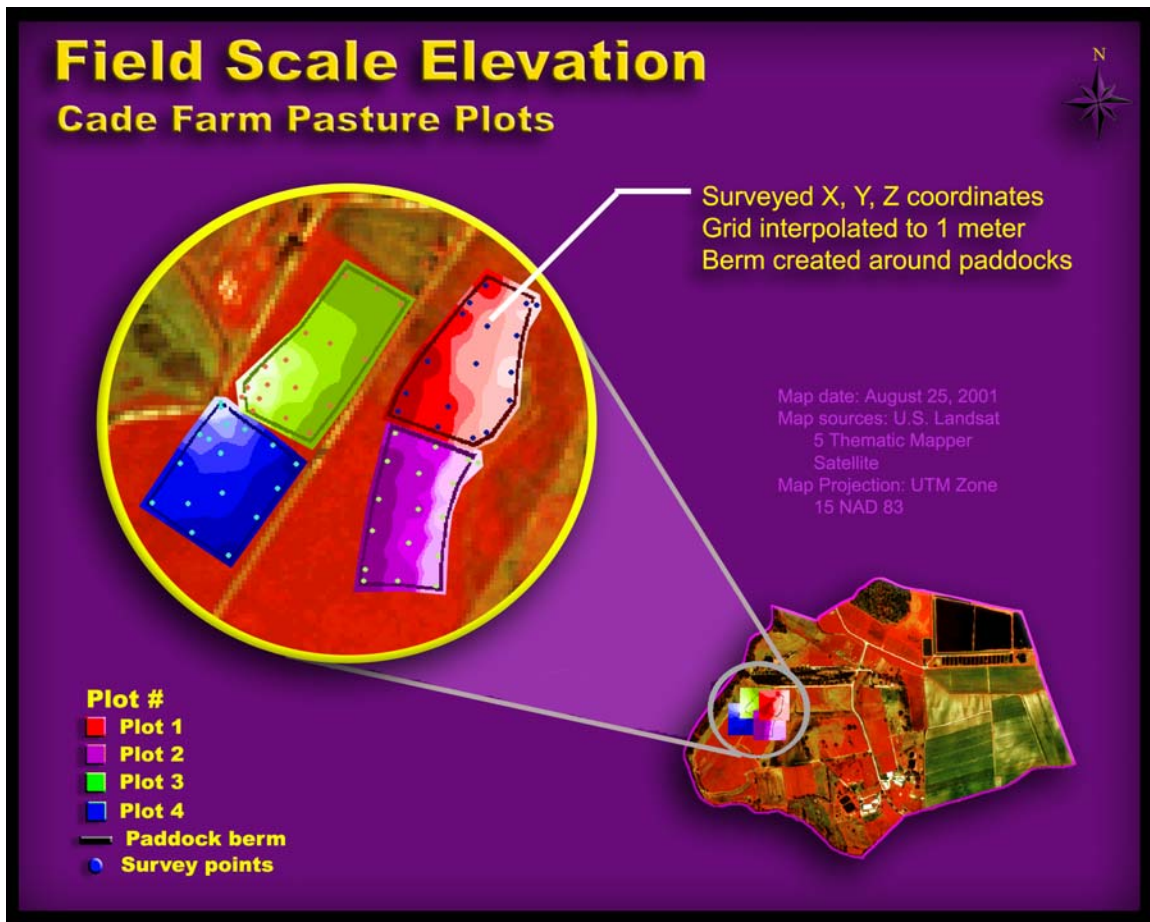


Figure 2.18. Interpolated Digital Elevation Models from field-scale plot, berm and flume elevation data.

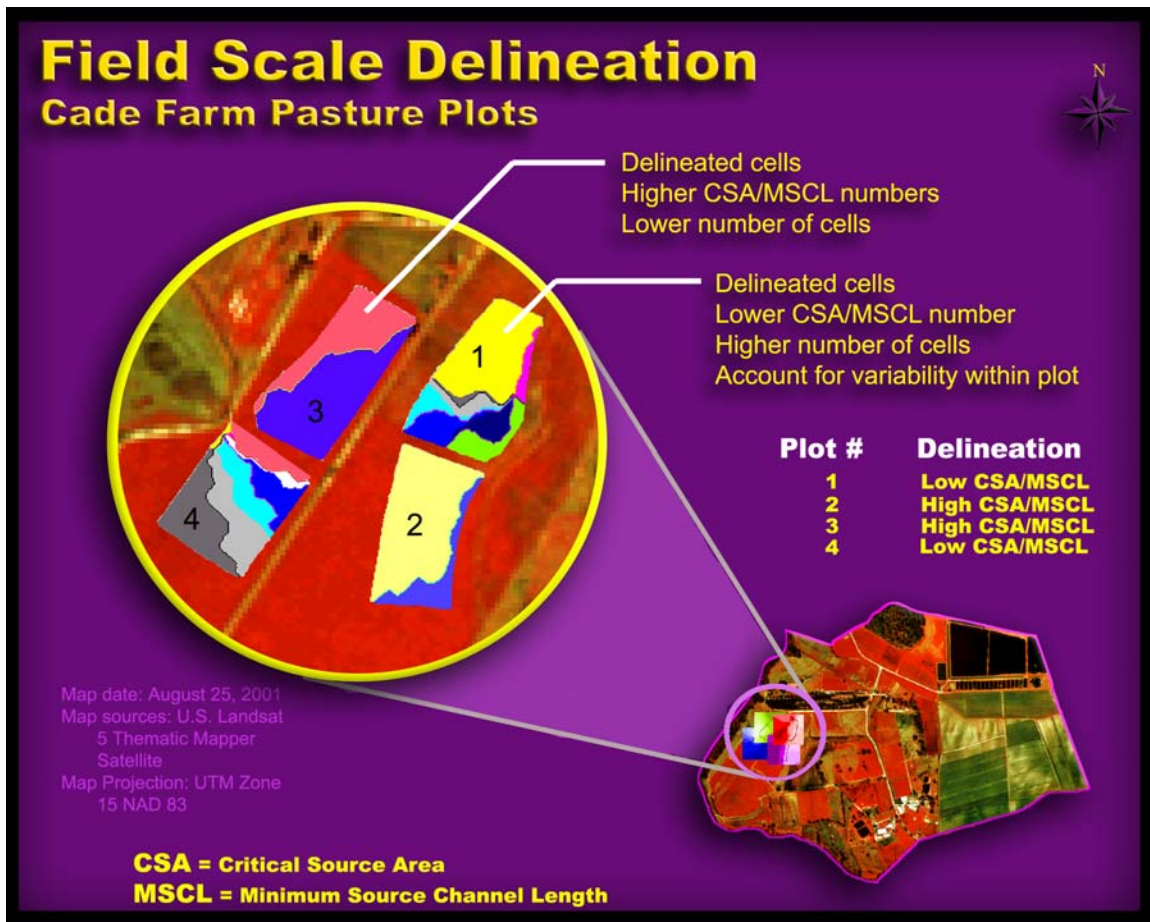


Figure 2.19. Cade Farm field-scale artificial delineation method demonstrating use of Critical Source Area / Minimum Source Channel Length values for variability accountability.

CHAPTER 3

ACCELERATED SEDIMENTATION IN A SMALL LAKE FOLLOWING LAND-CLEARING FOR ROW CROP AGRICULTURE

3.1 Introduction

Conversion of bottomland forest to row crop agriculture is expected to increase soil erosion and sediment deposition downstream. Extensive data on sediment yield to streams draining forest land in the eastern US (Patric et al., 1984) indicated nominal annual loadings of no more than about 0.6 Mg ha^{-1} . Craft and Casey (2000) found that resulting sediment deposition in forested depressional and floodplain wetlands was less than 0.1 cm yr^{-1} . In contrast, deposition rates in wetlands downstream from agricultural land (McIntyre and Naney, 1991), waterways draining agricultural land and a downstream lake (Mitchell et al., 1983) or small reservoir (McIntyre, 1993) were more than an order of magnitude greater. Sedimentation rates were even higher earlier in the past century when more of the upstream landscape was in cultivation (McIntyre, 1993; Craft and Casey, 2000) and before adoption of conservation practices (Mitchell et al., 1983). Besides change in land use from forest to row crop agriculture markedly increasing sediment loading, very heavy sediment yields to stream may occur during the conversion process. Assuming that sediment loading from an extensive network of logging roads (Megahan and Kidd, 1972) approximates that from cleared land, there may be nearly a 1000-fold increase in sediment discharge relative to background loss from forest land.

Between 1970 and 1975 a large portion of bottomland forest along the Red River in Avoyelles Parish, Louisiana, was cleared for row crops. This area (Figure 3.1) is near the confluence of the Red River and the Mississippi River. The topography is generally

flat or gently sloping, however, steeper grades occur on exposed or buried loess that was deposited before the more recent Red River alluvium. This area has numerous small lakes interconnected by bayous that once were perennially navigable by small boats. However, this is no longer the case and, ironically, one of the larger, open bayous, L'Eau Noire (Fr. black water) is now turbid and red. Though such anecdotal evidence suggests water quality degradation, neither the extent to which accelerated erosion has filled many of these small lakes and bayous nor how effective conservation practices may have been in mitigating sedimentation were known.

A widely used marker for age of sediments is the concentration of radioactive ^{137}Cs (Ritchie and McHenry, 1990) from the atmospheric testing of nuclear weapons, which peaked in 1963. In addition, the distribution of anthropogenic Pb, as from earlier leaded paint, gasoline and industrial emissions (Mielke, 1994), may corroborate ^{137}Cs data. Concentration of Pb in surface agricultural soils in the Lower Mississippi Valley averages 18 mg kg^{-1} , second highest of any region in the conterminous US (Holmgren et al., 1993). Given an estimate of sediment accumulation since land conversion, together with a history of cultural practices, these data may be used to calibrate any of several water quality models (e.g., Chemicals, Runoff and Erosion from Agricultural Management Systems, CREAMS, Knisel, 1980; Water Erosion Prediction Project, WEPP, Lane and Nearing, 1989; Agricultural Non-Point Systems, AGNPS, Young et al., 1989) such that simulated sediment load and textural composition account for measured sediment accumulation. A calibrated water quality model may be used to estimate benefits of conservation practices on reducing sediment accumulation.



Figure 3.1. The Lake Bettevy Area Of Interest location within state, parish and sub-segment boundaries.

Thus, the first objective of this project was to quantify recent (post-forest, 1973) sedimentation in a representative small (about 2 ha) lake. This objective was addressed in the LSU College of Agriculture undergraduate research projects, Strategies for Reducing Sediment Discharge from Agricultural Fields in Avoyelles Parish (Lindsey et al., 2000; undergraduate principle investigators) and Characterization of Erosional Processes in Agricultural Fields in Avoyelles Parish, Louisiana (Judice et al., 2001; undergraduate principle investigators). The second objective was to model sedimentation in this lake had the surrounding row-crop land been managed using conservation practices. The GIS-based AnnAGNPS (Annual AGNPS, Darden and Herring, 1999)

watershed-scale water quality model was used for the second objective. This model has been adopted by the Louisiana Department of Environmental Quality for preliminary assessment of best management practices (BMPs) likely needed to meet total maximum daily loads (TMDLs, including suspended solids) set for water quality standards.

Research conducted by the author was toward meeting the second objective. However, since the modeling work depended on field data, experimental aspects of the overall project are also discussed below. A clear understanding of the field experiment should aid understanding of the water quality and sedimentation modeling.

3.2 MATERIALS AND METHODS

3.2.1 Preliminary Observations

Following protracted drought in 1998 and 1999, the lake was almost dry, allowing direct access to the lake bed. Auger sediment samples and depths were taken from three (banks and center) to five (also between banks and center) locations along four lines transverse to the length of the lake in the Fall 1999. Since initial observations with depth revealed an abrupt discontinuity in color and density, depth to this discontinuity was measured along three additional transects using a 4 m long probe. Endpoints of each transect were permanently marked and distances along transects to sample locations were recorded.

3.2.2 Sediment Sampling and Lab Analyses

Seven sediment cores were later collected from preliminary sampling locations (three from the lake center and four between bank and center). These were taken as a series of separate 50 cm segments using a 5 cm diameter peat sampler. Segments were cut into 25-cm increments, downward from the current lake bed, except immediately

above the sediment discontinuity. Sediment samples immediately above and below this break were taken with an auger. Samples were air-dried, ground and sieved prior to laboratory analyses for texture by the hydrometer method (Gee and Bauder, 1986), organic matter by wet digestion (Nelson and Sommers, 1982), ^{137}Cs by gamma emission (DeLaune et al., 1978) and Pb by ICP after extraction with HCl-HNO₃ (McGrath and Cunliffe, 1985). Particle size distributions (Gee and Bauder, 1986), including fine clay fraction, were determined for segments from the center of the lake. These data were used to calculate mass-weighted mean radii of separates (in turn, used in sedimentation modeling as discussed below). Sediment bulk density was also determined.

3.2.3 Lake / Landscape Survey and Soil Sampling

Since the volume of recent sediment, as well as depth, was pertinent to assessing lake (and surrounding landscape) degradation, a point-wise survey of the lake edge was made using a total survey station. This established the area of the lake at zero depth of sediment accumulation, from which, together with depth of sediment at different locations in the lake, volume of recent sediment was calculated. In addition, slopes of drainage areas adjacent to the lake were measured. Given the coarse resolution of available digital elevation models (DEMs) for the study area, this step provided detail later needed in modeling sediment yields.

Preliminary analysis of the hydrology of the study area based on DEMs did provide, however, approximate delineation of cells contributing to flow into and through the lake. Overlay of the hydrologic cells on soil mapping units (Martin, 1986) were used in assigning values to soil parameters used in AnnAGNPS (modeling discussed below), however, fidelity of soil survey mapping unit delineations for several cells in the

immediate vicinity of the lake was confirmed from soil samples taken from these cells. Field observations included depth to underlying loess for the predominant soil in the study area, Solier (clayey over fine-silty, mixed, nonacid thermic Aeric Haplaquepts). Also, surface soil texture was determined. Soil sampling locations were determined by GPS and referenced to hydrologic cells.

3.3 MODELING RECENT SEDIMENT ACCUMULATION

3.3.1 AnnAGNPS Delineations

The study lake is located within the Marksville North and Lac Sainte Agnes 1:24,000 USGS quadrangle boundaries, Little River sub-segment, and the Red River watershed. The Marksville North and Lac Sainte Agnes DEM (7.5 degree, 30 meter) files were acquired, processed (merged and clipped) using ArcView, and converted to TopAGNPS format using the AnnAGNPS conversion program. TopAGNPS input files were created, and used with the TopAGNPS and AGFlow programs to delineate a naturally occurring watershed. The delineation process was repeated until cell and reach size, arrangement, and location represented local field and hydrologic conditions. This process created 67 hydrologic cells, 28 reaches and a total area of 3880 ha. The coarse resolution of DEMs resulted in inaccurate cell flow slopes and related RUSLE 'ls' factors (corrections to these parameters discussed below).

3.3.2 AnnAGNPS Input and Climate Data

Digitized soil series and characterization data (obtained from soil survey and the NRCS soil characterization database) were used for soil input parameters for hydrologic cells. However, series was confirmed and site-specific texture determined for several of the contributing cells. Satellite imagery, land operator records and field observations

established dominant land use, contour, crop, and field input data. The dominant land use in this AOI has been soybean production during the past 30 years. The conventional soybean operations begin in late March (or early April) with the disking and smoothing with harrow for weed control and increased tilth, followed by fertilizer (200 lbs 0-20-20, commonly) and pre-emergent herbicides. A mid-April planting with narrow rows (20 inches) is typical. Post-planting cultivation is performed twice (early May and August) for weed control and soil loosening. A September harvest was assumed to leave 50% coverage with residue but residue was later disked into the soil and no cover crop planted. As specified in the National Engineering Handbook (SCS, 1972), runoff curve numbers were assigned based on land use, crop, management practice and hydrologic soil group.

The GEM (Generation of weather Elements for Multiple applications; Johnson et al., 2000) weather generator model was used to create the climate output file. The mean precipitation (Martin, 1986) and Alexandria, LA. weather station data were used to create the GEM output file. This file was used, in conjunction with monthly climate data, to create the 30-year AnnAGNPS climate input file.

3.3.3 Model Calibration Based on Sediment Depth and Composition

The study lake is a depressional area at an intermediate position in the local landscape. Although naturally subject to flooding from the Red River, manmade levees along the river have prevented this since before the surrounding land was cleared for agricultural production. In addition to direct runoff from large fields on both sides, it ordinarily receives other runoff through two channels and is drained by another. However, heavy runoff may cause all three channels to pool into the lake and later simultaneously drain it. The hydrology of the study site was aptly described in Martin

(1986) as consisting of “irregular undulating or ridge and swale topography, intricate and complex drainage patterns, and a lack of drainage outlets in low areas.”

Given the hydrologic complexity of the area, AnnAGNPS could not be directly applied to estimate sediment load entering and leaving the lake. Instead, the model was used to estimate concentration and composition of suspended sediment from the two cells that discharge directly into the lake, and model parameters were adjusted such that recent accumulation of sediment (depth and texture) in the lake best matched sediment data. Sediment accumulation was assumed to be described by Stokes’ Law (for constant water density and viscosity with depth and time) and mean particle sizes of separates were used rather than particle sizes for the several measured sub-classes. Additional assumptions (and justifications) were: 1) complete recharge of the lake with water of uniform sediment composition and concentration during each runoff event (lake is very small compared to the area from which it receives runoff); 2) no re-suspension and loss of sediment previously deposited in the lake (negligible scour, especially towards center and during first years of accelerated sediment deposition); 3) no sedimentation during outflow (discharge is fast compared to settling rate of mostly fine suspended sediment); and 4) negligible effect of evaporation from the lake (recharge events are frequent).

Model calibration was an iterative process. Target values for sediment composition and concentration were those generated using Stokes’ Law and average number of recharge events (as predicted from the model using synthetic rainfall data) that predicted the known depth and texture of recently accumulated sediment. Target values were 0.965 for clay fraction and a density of 6.00 g of sediment per L⁻¹ of water for runoff. Initial predictions using the un-calibrated model were 275,100 and 433,000 m³/yr

water loading, 108.4 and 81.28 Mg/yr landscape clay yield, 345.5 and 254 kg/yr landscape silt yield, and 109.2 and 82.2Mg/yr total landscape sediment yield for cells 122 and 123 (those discharging directly into the lake), respectively. Accordingly, average discharge from cells 122 and 123 contains 0.35 and 0.17 g/L suspended solids, respectively, which is about 99.7% clay. Clearly, sediment load and composition predicted by the un-calibrated model could not account for sediment deposition. Based on a sensitivity analysis (0.1, 0.25 and 0.50) for impact of various input parameters on predicted values, runoff curve numbers (typical calibration parameter), cell slope (reasons defined previously) and slope dependent RUSLE 'ls' factors were the parameters selected for model calibration.

3.3.4 Predicting Sediment Accumulation under Conservation Management Practices

Use of a calibrated water quality model enables the researcher to estimate benefits of various conservation practices or BMPs. Model calibrations were performed using conventional soybean management practices (no conservation practices), details of which were determined via landowner interviews. Current practices have been performed in this region since conversion to row crop agriculture began. The following BMP scenarios were evaluated: soybean no-till system, soybean no-till with cover crop system, and a forest system.

No-till systems for row crop operations reduce soil disturbance and runoff. The no-till soybean system permits closer spacing of rows (as little as 10"), planting directly into existing stalks and weed bed, and herbicides for weed control. No cultivation is required for weed control and the soil has only minimal disturbance throughout the

season. Recommended runoff curve numbers for no-till systems are 10 units below the standard row crop curve numbers.

A forage plant system was added to the no-till soybean system to approximate no-till soybean with cover crop management. The close spacing of cover crops, coupled with improved soil structure and permeability, provide good protection against erosion (Troeh, 1999). Runoff curve numbers for the forage plant system were 66, lower than with no-till.

Forest system predictions allow for the assessment of impacts of current management and conservation row crop management, versus pristine conditions. Forest cover, combined with undergrowth and a litter layer, provide strong protection against erosion. Forest systems reduce erosion by intercepting raindrops, slowing the velocity of runoff and increasing infiltration rates (Troeh, 1999). As above, runoff curve numbers for the forest system were further reduced to compensate for reductions do to calibration.

3.4 RESULTS AND DISCUSSION

3.4.1 Sediment Morphology

Preliminary samples revealed an abrupt discontinuity in color and density with depth. Sediment above the break had reddish colors typical of Red River alluvium whereas material below was strongly gleyed. Sediment above the break was easy to bore through whereas that below was much denser. Furthermore, fragments of mussel shells and pieces of apparently charred wood were often found in sediment samples immediately above this discontinuity. Since trees cleared from the surrounding land had been burned on site, coincidence of charred wood (see Patterson et al., 1987, for an earlier review of charcoal analysis in palaeoecological reconstructions) and mussel shells

suggested that the original lake bed lay just above the dense, gleyed material. Evidence was strongest for samples taken near the lake bank.

3.4.2 Radioactive Cesium

Results for ^{137}Cs concentration in sediment generally supported the above observations. Figures 3.2A through 3.2C show the distribution of fallout ^{137}Cs with depth in sediment towards the southern bank along transect 1 (Fig. 3.2A) and in the center of the lake along transects 1 and 3 (Figs. 3.2B and 3.2C, respectively). At all locations, first appearance of ^{137}Cs marks the lake bed prior to land clearing in 1971. For sediment near the lake bank, this depth was just above the discontinuity in sediment material but for sediment from the lake center, lay about 1 m above the discontinuity. Depth of recent sediment accumulation was greater in the center of the lake and increased in the center from transect 1 to 3.

All profiles had highest ^{137}Cs concentration near the current lake bed. Occurrence of the upper local maximum in ^{137}Cs likely reflects the combined effects of surface soil disturbance, particularly surface soil inversion with the first tillage operations, mixing with continued tillage and erosion. In sequence, these effects would reduce the concentration of ^{137}Cs in the first sediment deposited. But continued mixing of inverted surface and subsurface soil would lead to an increase in the ^{137}Cs concentration of soil subject to erosion. A maximum in ^{137}Cs for in-lake sediment would be expected since, as erosion proceeded, tillage would introduce soil with little ^{137}Cs into the plow layer.

3.4.3 Lead

Profiles of Pb concentration in sediment (Figs. 3.3A through 3.3C with sample locations as Fig. 3.2) were generally consistent with ^{137}Cs profiles, however, the upper

local maxima in Pb concentrations were not greater than the lower maxima. In part, this result may be due to the extraction procedure. Hot $\text{HNO}_3 + \text{HCl}$, though a vigorous digestion agent, does not yield total Pb. Thus, differences in texture, particularly clay content, within the sediment profile may also have affected recovery of Pb by this method.

3.4.4 Clay

The distribution of clay with depth for these sample locations is shown in Figs. 3.4A through 3.4C. Clay content of lake sediment above the lower maxima in ^{137}Cs and Pb was greater than below. This suggests a recent change in sediment source. Although the lake is surrounded by Solier (consisting of a 60+ % clay mantle of alluvium over buried loess), if erosion in the earlier bottomland hardwood forest had been small, a substantial fraction of lake bed sediment may have originated elsewhere. Coarser soils nearer the Red River and higher on the natural levee had been in production for years before land surrounding the lake was cleared.

3.4.5 Organic Matter

Assuming accelerated decomposition of organic matter due to tillage of the cleared forest land, together with soil inversion, sediment from nearby soil might be expected to have contained less organic matter than earlier lake sediment. However, the finer texture of Solier sediment might offset this effect. The distribution of organic matter with depth for lake sediments is shown in Figs. 3.5A through 3.5C. In general, organic matter content was higher in sediment where clay content was low. Thus, the former effect was apparently dominant.

3.4.6 AnnAGNPS Calibration to Sediment Depth and Composition

The calibrated runoff curve numbers for soil hydrologic group D (cells 122 and 123) were 70 for fallow cover, 79 for soybean cover and 71 for weed cover. The sheet and concentrated flow slopes of 0.00003 for cells 122 and 123 were also used and the RUSLE 'ls' factors were adjusted to 1.90 for cell 122 and 1.93 for cell 123. These adjustments resulted in predicted values (Table 3.1) of 0.966 for clay fraction and a density of 5.99 g L⁻¹ for cell 122, and a 0.968 clay fraction and a density of 5.93 g L⁻¹ for cell 123. Results from the calibrated model simulations described in-lake average sediment texture. The calibrated model simulations (based on center core data) for conventional soybean systems also predicted sediment accumulations (Figure 3.6). For 30 runoff events yr⁻¹, total sediment yields were 1,000 Mg yr⁻¹ for cell 122 and 1564 Mg yr⁻¹ for cell 123. Depths to lower maxima in ¹³⁷Cs and Pb concentrations and depth to change in sediment texture, together with lake surface area, were used to estimate volume of sediment after onset of accelerated deposition. These calculations indicate recent accumulation of about 9,000 m³ of eroded soil or about 4,800 Mg (average bulk density of 0.54 Mg m⁻³ oven dry mass per volume of wet sediment). However, over the past 30 years 2,300 Mg yr⁻¹ were discharged into the lake from cells 122 and 123 alone. Thus, < 7% of sediment yield has been trapped in the lake.

3.4.7 Predicted Effect of Conservation Management on Sediment Accumulation

Model simulations for no-till soybean systems with runoff curve number = 71 predicted (Table 3.1) a 0.97 clay fraction and 1.66 g L⁻¹ density for sediment accumulation, and a 268 Mg total sediment yield for cell 122. Predictions for cell 123 were a 0.97 clay fraction and 1.65 g L⁻¹ density for in-lake deposition, and total sediment

yield of 419 Mg. Simulations for no-till soybean with cover crop (runoff curve number = 66) systems predicted a 0.97 clay fraction and a 1.18 g L^{-1} density of accumulated sediment, and 167 Mg total sediment yield for cell 122 (Table 3.1). Predictions for cell 123 were a 0.97 clay fraction and a 1.18 g L^{-1} density for in-lake deposition, and total sediment yield of 261 Mg. Simulations for forest systems (runoff curve number = 63) predicted a 0.94 clay fraction and a 0.09 g L^{-1} density for accumulated sediment, and 10.4 Mg of total sediment yield for cell 122 (Table 3.1). Predictions for cell 123 were a 0.95 clay fraction and a 0.09 g L^{-1} density for in-lake accumulated sediment, and total sediment yield of 16.3 Mg (30 years).

Average sediment predictions for current conventional soybean operations versus no-till, no-till with cover crop and forest operations are shown in Figure 3.7. The no-till system reduced sediment yield by > 70 % for cells 122 and 123. The no-till with cover crop system reduced the sediment yield by nearly 85%. The forest system reduced sediment yield by 99%.

Average sediment accumulation predictions for current conventional soybean operations versus no-till, no-till with cover crop and forest operations are shown in Figure 3.8. The no-till system reduced sediment accumulation by 72% for cells 122 and 123. The no-till with cover crop system reduced sediment accumulation by 80 %, and the forest system reduced sediment accumulation by 98 %.

3.5 SUMMARY AND CONCLUSIONS

As bottomland forest is converted to row crop agriculture, an increase in erosion and downstream sediment deposition can be expected. This research used sedimentation data to first calibrate a water quality model, then use the calibrated model then evaluate

the effects of no-till, no-till with cover crop and forested land use systems on sediment yield and accumulation. Results show a significant decrease in sediment yield and in-lake sediment accumulation when these BMPs operations were used. Additional research could assess the benefits of using combined BMPs, such as forested buffer strips (given forest systems negligible sedimentation) in conjunction with in-field conservation operations. Water quality models allow us to better assess management options and make improved decisions regarding water related resources.

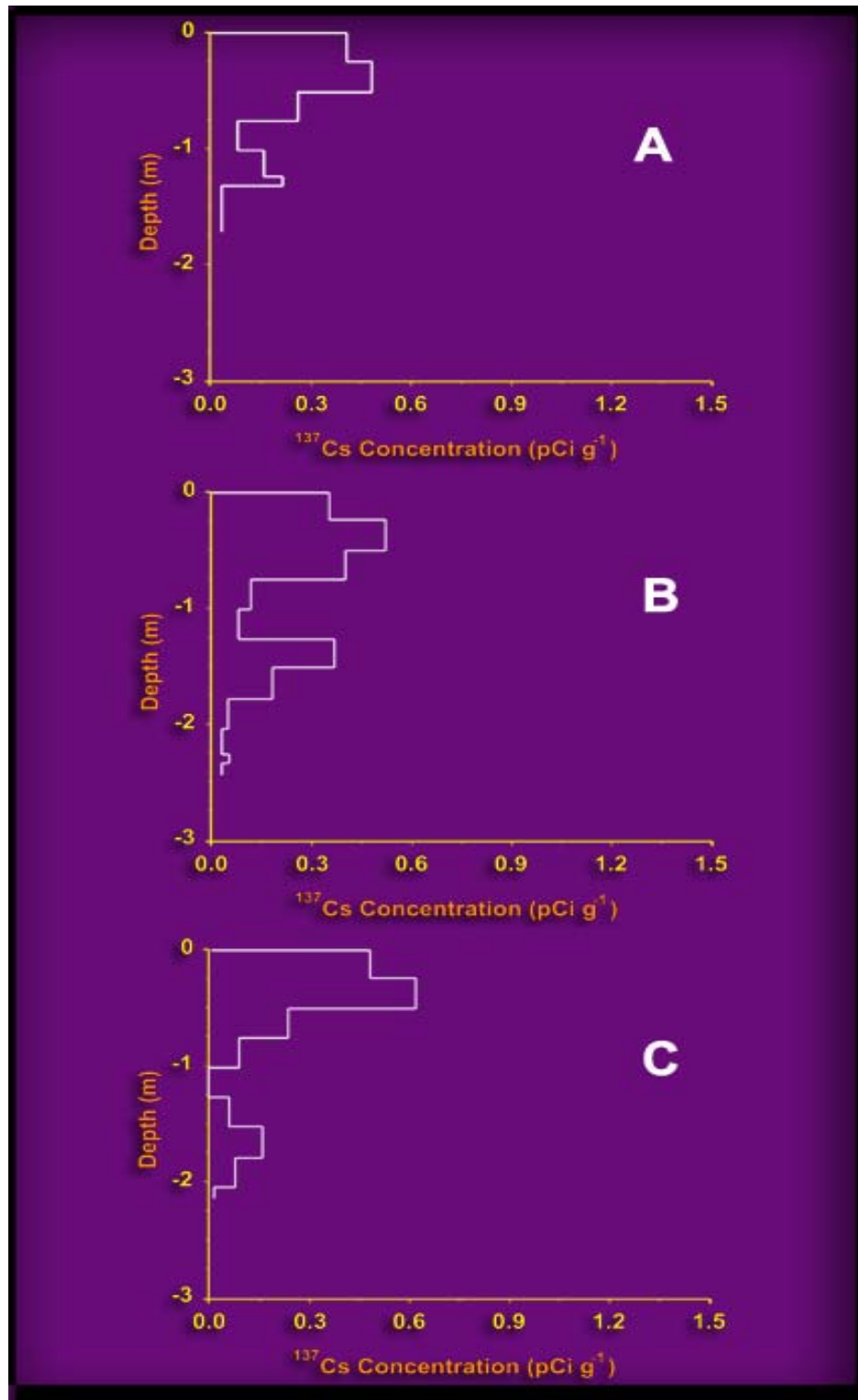


Figure 3.2. Concentration of ^{137}Cs in lake sediment with depth below the current lake bed along transect 1 near bank (A), in lake center (B), and along transect 3 in lake center (C).

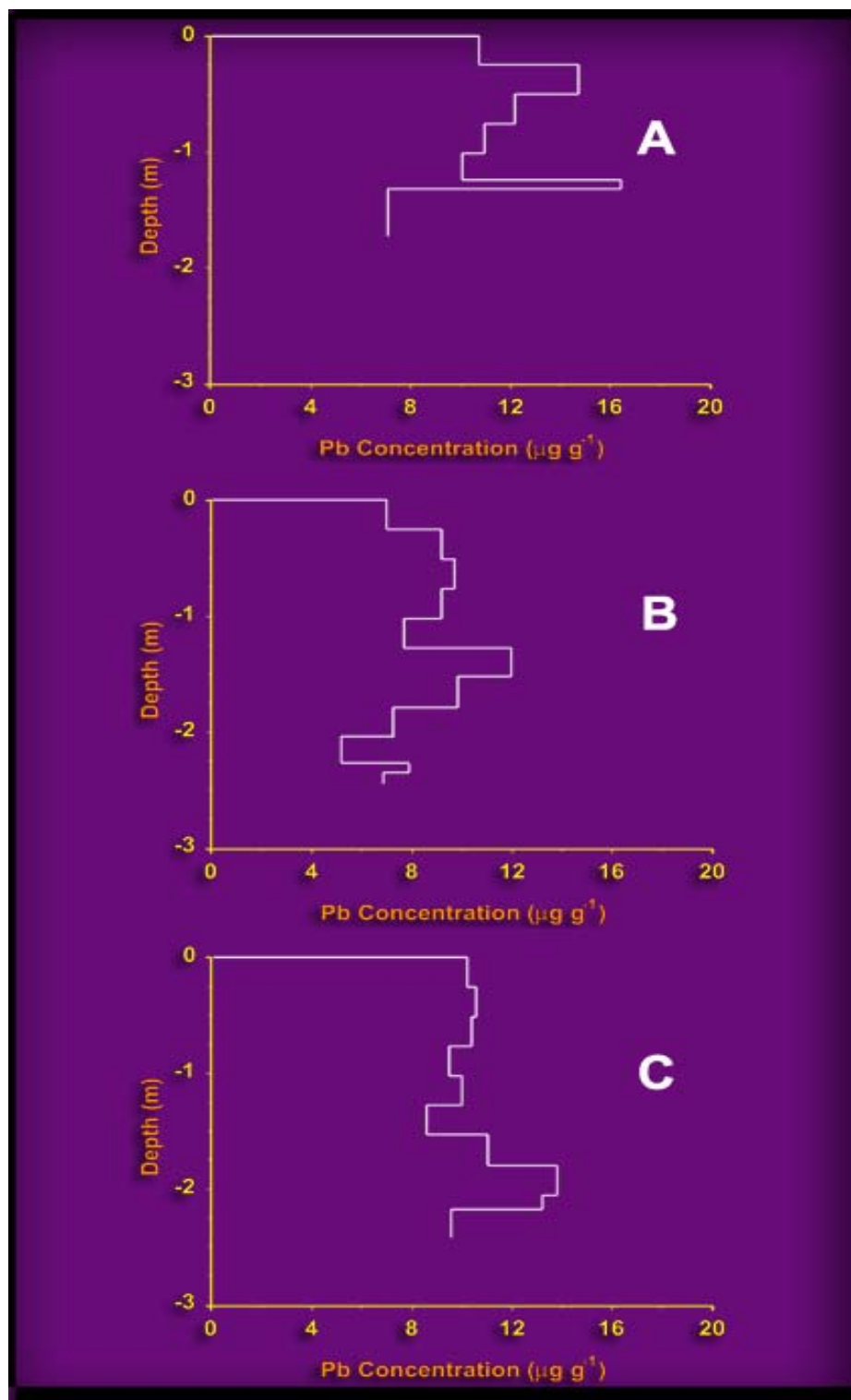


Figure 3.3. Concentration of Pb in lake sediment with depth below the current lake bed along transect 1 near bank (A), in lake center (B), and along transect 3 in lake center (C).

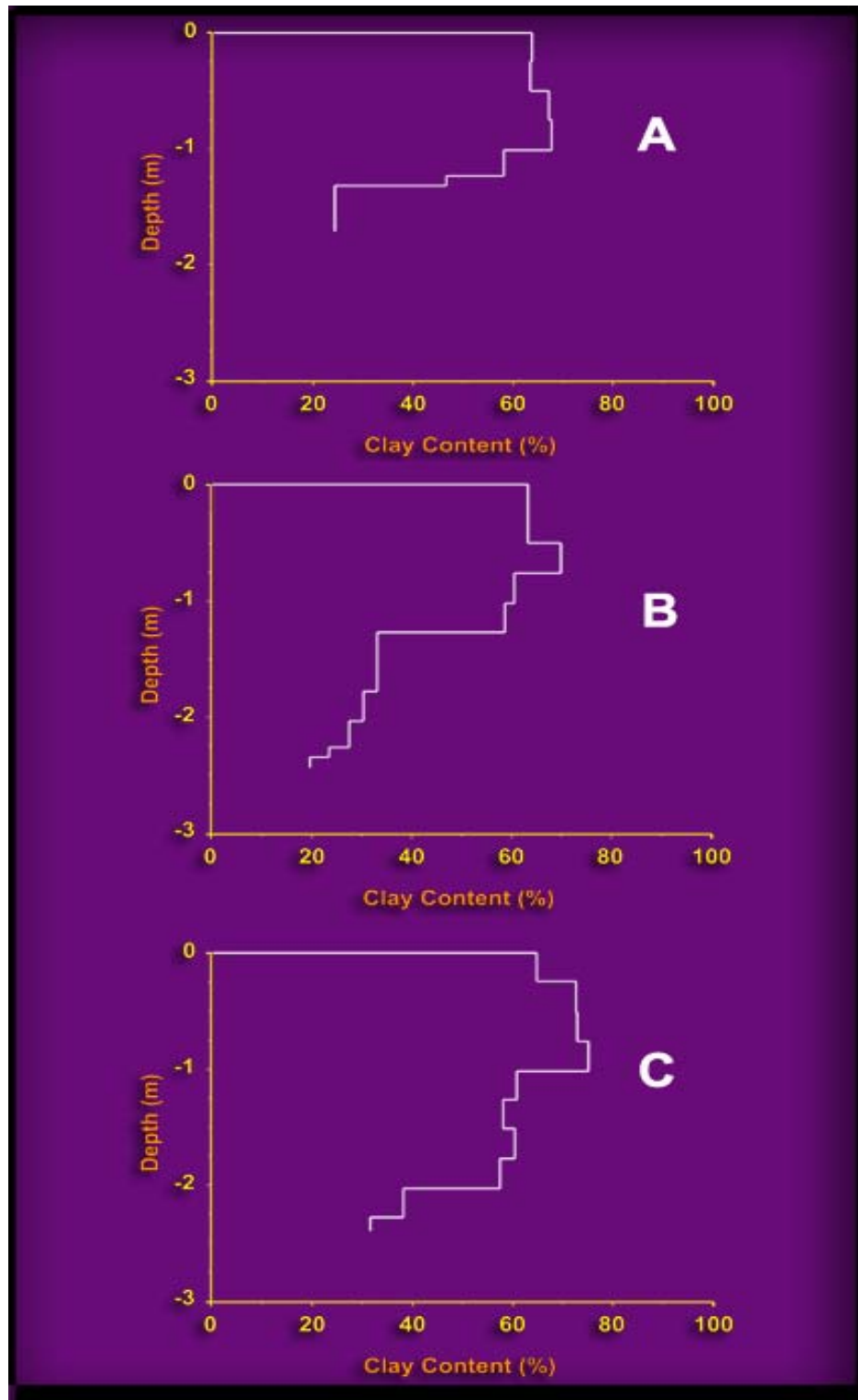


Figure 3.4. Clay percentage in lake sediment with depth below the current lake bed along transect 1 near bank (A), in lake center (B), and along transect 3 in lake center (C).

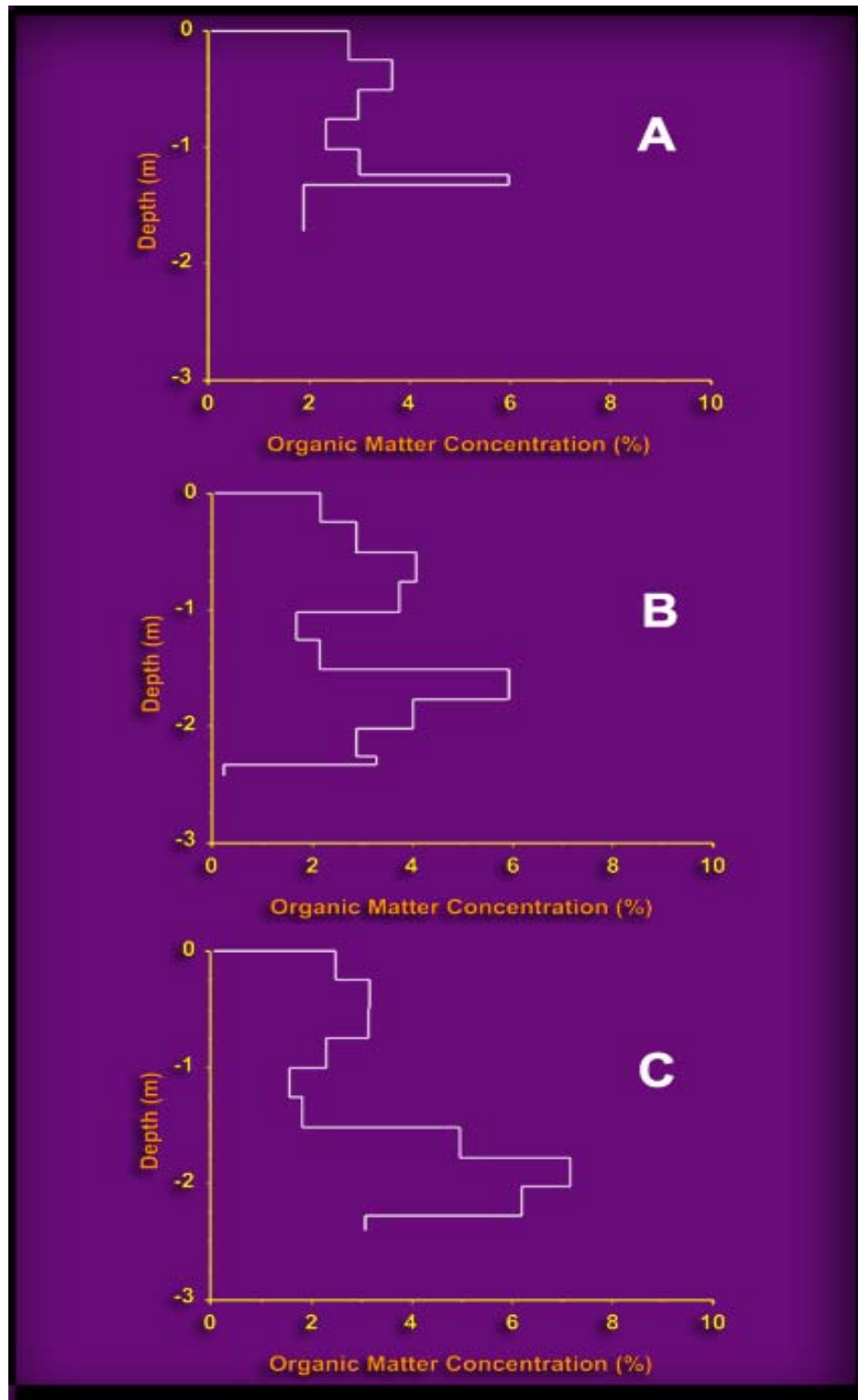


Figure 3.5. Content of organic matter in lake sediment with depth below the current lake bed along transect 1 near bank (A), in lake center (B), and along transect 3 in lake center (C).

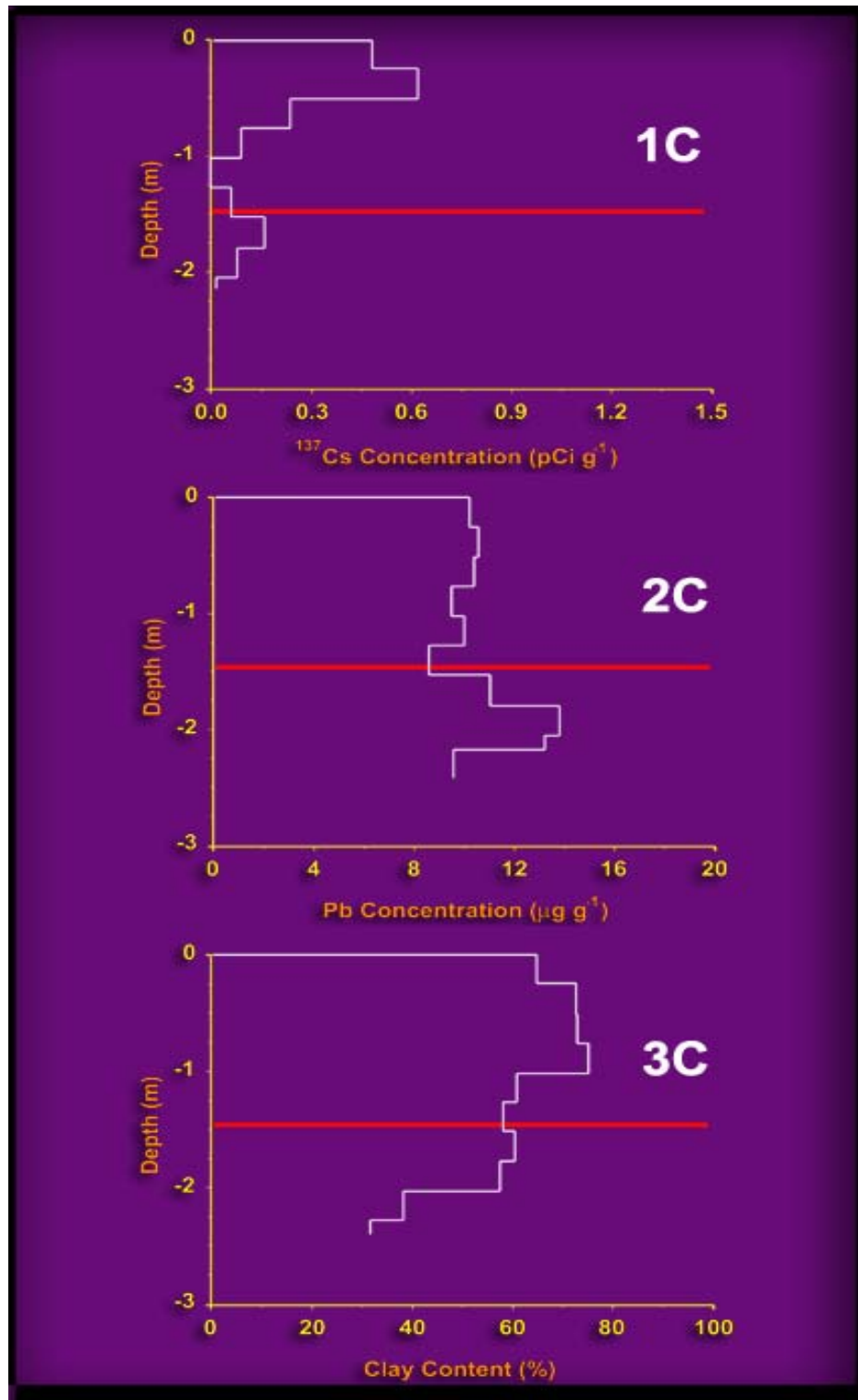


Figure 3.6. Calibrated model predicted original lake bed (red line) versus concentration of ^{137}Cs (1C), Pb (2C) and clay content (3C) in lake sediment with depth below the current lake bed along transect 3 in lake center.

Table 3.1. Calibrated model predictions of sediment yield, clay fraction, density, runoff events, and deposition under various management practices for cells 122 and 123.

Cell Identifier	Operation	Sediment yield (Mg/yr)	Clay Fraction	Density (g/L)	Runoff events/yr	Deposition (cm)
122	current	1000	0.9656	5.9861	30.0	148.9
	no-till	268	0.9694	1.6588	24.6	42.0
	no-till/cover	167	0.9649	1.1833	21.9	30.2
	forest	10	0.9426	0.0916	18.5	2.7
123	current	1564	0.9682	5.9289	30.0	145.4
	no-till	419	0.9711	1.6493	24.6	41.1
	no-till/cover	261	0.9661	1.1800	24.6	29.8
	forest	16	0.9432	0.0911	18.5	2.6

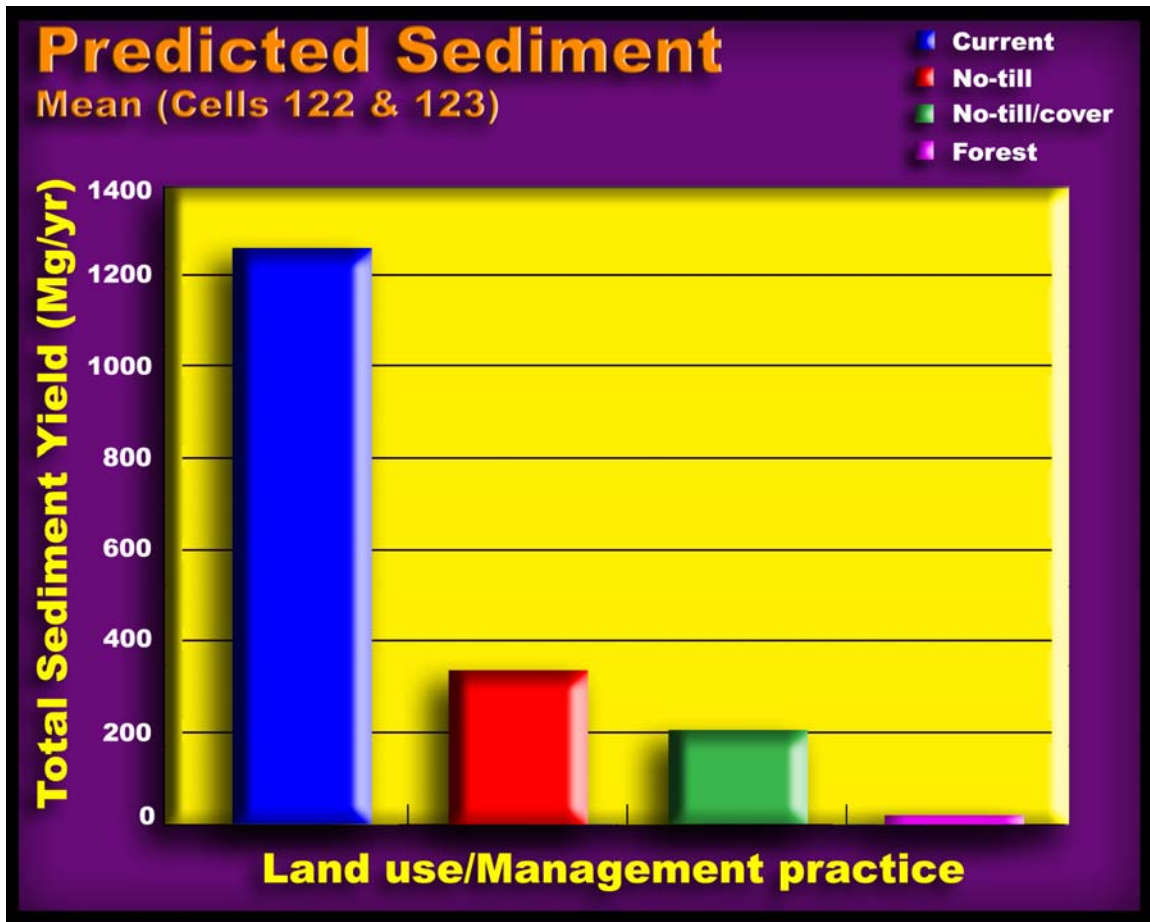


Figure 3.7. Calibrated model predicted average total sediment yield for cells 122 and 123 with current, no-till, no-till with cover crop and forest management practices.

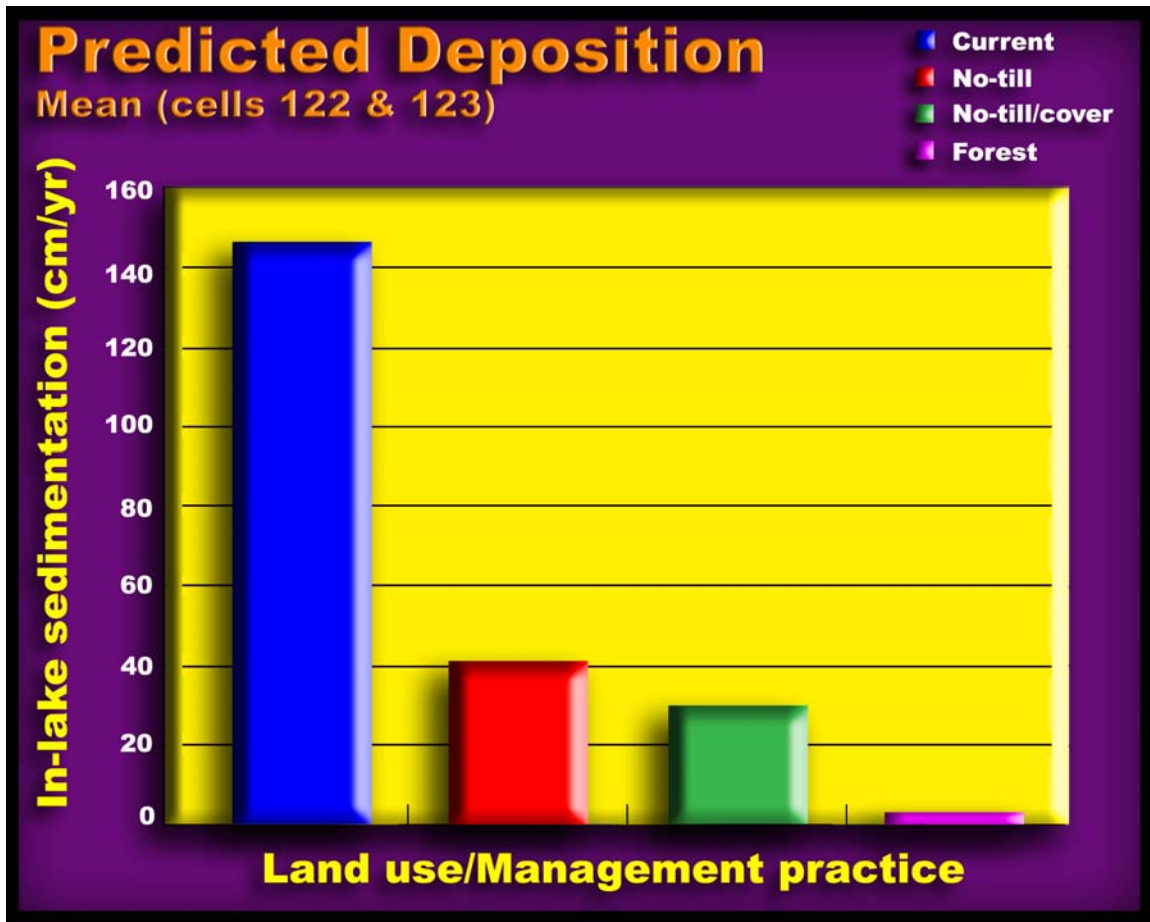


Figure 3.8. Calibrated model predicted in-lake average sediment accumulation for cells 122 and 123 with current, no-till, no-till with cover crop and forest management practices.

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APPENDIX A: ARCVIEW AVENUE SCRIPT FOR ASCII TO DEDNM FORMAT CONVERSION

```
' Spatial.Export

' set types of files to export
if (av.Run("Surface.IsClassAvailable",{ "Tin" })) then
  fileTypeList = {"ASCII Raster","Binary Raster"}
  fileType = MsgBox.ChoiceAsString(fileTypeList,"Select export file type:","Export File
Type")
  if (fileType = NIL) then
    return NIL
  end
else
  fileTypeList = {"ASCII Raster","Binary Raster"}
  fileType = MsgBox.ChoiceAsString(fileTypeList, "Select export file type:","Export File
Type")
  if (fileType = NIL) then
    return NIL
  end
end

' call proper script to perform export
if (fileType = "ASCII Raster") then
  av.Run("Surface.GridExport",{fileType})
elseif (fileType = "Binary Raster") then
  av.Run("Surface.GridExport",{fileType})
else
  return NIL
end

'run the model
system.execute("C:\Agnps\agnps2001_watershed_studies\BASE\0_batch_files\9_execute
_convARC.bat")
```

APPENDIX B: ANNAGNPS CONVERT ARC BATCH SCRIPT

```
echo off
cd c:\AGNPS\AGNPS2001_WATERSHED_STUDIES\BASE\1_TopAGNPS_DataSets\

echo **** Starting Convert Arc ***
c:\AGNPS\AGNPS2001_Watershed_Studies\BASE\1_TopAGNPS_Datasets\conv_arc.exe

pause
echo off
copy xport2.asc BASE_dednm.inp

echo *****
echo **** Execution of Convert ARC completed! ****
echo *****
```

VITA

Glenn Michael Suir was born December 24, 1972, in Morgan City, Louisiana. He was raised in Lafayette, Louisiana, where he graduated from Northside High School in the spring of 1991, and enrolled at the University of Southwestern Louisiana. He received his undergraduate degree in environmental and sustainable resources in December 1999. He enrolled at Louisiana State University in January 2000 to pursue a master's degree in Agronomy. He is married to the former Rachelle Rae Guidry of Buras, Louisiana.